ENVIRONMENTAL EFFECTS OF SURFACE MINING OF MINERALS OTHER THAN COAL: ANNOTATED BIBLIOGRAPHY AND SUMMARY REPORT

USDA Forest Service General Technical Report INT-95
Intermountain Forest and Range Experiment Station
U.S. Department of Agriculture, Forest Service

This bibliography was compiled from various sources including computerized data bases, personal literature collections, and the results of a national survey. We have strived to achieve as much consistency and accuracy as possible.

Because we will maintain this bibliography as an active computerized file and publish supplements to it from time to time, we would appreciate your help. If you encounter incorrect citations (perhaps of your own work or that of your colleagues) or know of citations we have missed, please send this information to:

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COVER PHOTOS

Problem: A western copper cobalt open pit with waste dumps radiating in all directions. Waste dumps consist mainly of acid-forming sulfide minerals. The white areas are primarily magnesium and aluminum salts. The blue areas indicate severe phytotoxic concentration of metallic ions. Natural vegetation is predominantely lodgepole pine and subalpine fir.

Research: The squares of varying intensities of green and tan show results of vegetation research utilizing chemicals, fertilizer, mulch, and various mixtures of plant species.

Application: The best combination of treatments as determined through research is applied to waste dumps that were bare of vegetation for 20 years. White area in background is untreated. Dark green area in background is an undisturbed lodgepole pine stand. The deeper shade of green in the foreground indicates greater species density and is a reflection of treatments used in establishing vegetation. As succession progresses, grasses will give way to the natural invasion of lodgepole pine and subalpine fir.

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This bibliography was prepared at the request of the Committee on Surface Mining and Reclamation (COSMAR), National Academy of Sciences, National Research Council, for use in developing the COSMAR report. The bibliography was funded by the Intermountain Forest and Range Experiment Station and the SEAM program of the USDA Forest Service.

PREFACE

Early in the spring of 1978 the National Academy of Sciences appointed a Committee on Surface Mining and Reclamation (COSMAR) and directed it to conduct an in-depth study of the current and developing technology of mining and reclamation operations for minerals other than coal. This study was intended to provide scientific and technical assistance in developing legislative recommendations for the establishment of effective and reasonable regulation of these activities where necessary and appropriate.

The present report was originally written for COSMAR. Its purpose was to determine and evaluate, wherever possible, the state of the art of mitigating adverse environmental effects of surface mining, and to aid members of the Environmental Subcommittee of COSMAR on the significance of environmental problems.

On November 14, 1978, the authors started an extensive computer-based search of literature using the Lockheed data vendor. Keywords used were generated from a preliminary manual search and a review of a checklist of known environmental problems developed by the Environmental Subcommittee. Data bases chosen for the search were those that appeared to be most comprehensive, and those that index materials most closely associated with surface mining and with the environment and natural resources.

The Office of Arid Lands Studies at the University of Arizona provides a current alerting service (SEAMALERT) that lists current literature about reclamation of surface mines. We used this service plus several data bases through the RECON data vendor at the University of Arizona.

In order to obtain as much current research information and important "soft" (unpublished) literature as possible, we conducted a national survey by sending an inquiry letter to some 340 knowledgeable persons. This letter asked for: (1) comments based on professional experience and research on significant environmental problems related to surface mining, and (2) citations, publications, and reports on current research. The letter was sent to mining associations; to persons presently conducting research on reclamation of surface mines; to environmental concern groups; and to all States' departments or divisions that are involved in reclamation of surface mines. All responses received were read, their citations cataloged, and their comments recorded.

Citations generated by the computer search (more than 1,500) were read and cataloged according to problem studied and commodity involved. Only citations that had direct relevance to the COSMAR study were selected for this bibliography. Available abstracts are included. Abstracts usually are those written by the authors of articles or reports, but some abstracts included here were available through the abstracting service within various data bases. Publications received in response to the survey were abstracted by the authors of this report.

All citations are grouped by general problem subjects and are cross-referenced in the Environmental Effects index. The index lists environmental effects/problems in an effort to make available as much information as possible and to organize this information into a useful tool.

RESEARCH SUMMARY

This bibliography was prepared at the request of the Committee on Surface Mining and Reclamation (COSMAR), National Academy of Sciences, National Research Council, for use in developing the COSMAR report. The bibliography determines and evaluates, wherever possible, the state of the art of mitigating adverse environmental effects of surface mining for commodities other than coal. It contains results of an extensive computer-based literature search and responses to a national survey. Citations that have direct relevance to the COSMAR study were selected for the bibliography. Available abstracts are included. Each reference is indexed by commodity, general subject, and environmental problem. The publication includes a section of references to unpublished literature and a summary of professional concerns about mining impacts throughout the United States.

GUIDE TO USAGE

Section I

Section I was compiled directly from responses to the inquiry letter. Therefore, it is a summary of professional concerns about reclaiming surface mined areas throughout the United States. The comments represent years of research or direct professional experience with surface mining and reclamation.

Comments are referred to by letter and numeral and are referenced at the end of the section. For example, B5 refers to the fifth entry under "B. Effects of Climate and Geography on Mitigation Efforts." It is a quotation from A. Bjugsted of the Rocky Mountain Forest and Range Experiment Station. Presumably the author of any comment can supply pertinent technical data to support his comment. Indeed, many did this, and citations are included in Section II.

Section II

Section II contains the body of technical data in the form of an annotated bibliography. Section II-A contains citations that refer to other bibliographies and comprehensive texts that deal primarily with reclamation of surface mines. These are cited primarily to give weight to major concerns as indexed by impacts. For example, in the Index of Environmental Effects the problem of acid mine drainage has references to four citations that are bibliographies (4, 10, 49 and 60). This indicates publication of much literature dealing with the problem of acid mine drainage, and that acid mine drainage may be a significant problem.

Section II-B lists citations to reports of current research projects and current unpublished literature. Sources for this section are discussed on page 22. This "soft" literature is important because technology is now being developed that may have important effects on mitigating measures.

Sections II-C through II-N contain citations to materials in print that are grouped according to primary subject matter. Citations within each subsection are listed alphabetically by authors' surnames. The first page of each subsection describes its contents. Citations in Section II are cross-referenced in two places: (1) the Index of Environmental Effects and (2) the Summary Matrix of National Trends.

In the Index of Environmental Effects, effects are grouped by major problem subjects (e.g., air-related effects, fauna-related effects, etc.). Under major subject problems, effects are listed separately (e.g., mass emissions, fine particles, respirable dust, etc.). The index has four columns. Citations to publications that describe environmental problems are listed in column 2. Citations to articles that describe solutions or mitigating measures are listed in column 3. Citations to items that do not clearly describe a problem or a solution (e.g., bibliographies, etc.) are listed under "Other Citations." Occasionally remarks have been made to clarify meanings of the citations.

For example, the general heading "Fauna-related Effects," has a subheading "Wildlife Habitat." Citation 515 is listed as a "citation describing a problem" associated with wildlife. It is entitled "Effects of Surface Mining on the Fish and Wildlife Resources of the United States." The abstract tells us that about 2 million acres of fish and wildlife habitat are damaged by mining. Citation 510, listed as a "citation describing a solution," is entitled "A Guide for Revegetating Surface Mined Lands for Wildlife in Kentucky and West Virginia." The abstract indicates that this guidebook is an aid to land managers in revegetating surface mined land areas for wildlife. It includes information about species, planting and seeding methods, and other mitigating measures.

CONTENTS

SECTION I.

COMMENTS ON SIGNIFICANT ENVIRONMENTAL EFFECTS

This section summarizes professional concerns about environmental problems expressed by interested individuals throughout the United States. These comments represent years of research or direct personal experience with surface mining and reclamation. Similar comments about specific problems were made by several persons, often representing industry, research, and environmental concern groups.

Environmental problems and comments in this section were compiled directly from responses to the inquiry letter and have not been edited. Most comments received are included without regard to conflicting opinions or to the authors' personal biases. These problems were judged by the responding individual to be "significant" on the basis of his experience or research. References for each comment are listed on pages 12-14.

A. Philosophy and Goals

1. Development of criteria (or processes) for evaluating the relative long-term costs to society for the extraction of needed minerals in relation to environmental and social costs as a basis for policy decisions.

2. How to define when ecosystem stability has occurred--and translate this into criteria or operational guidelines.

3. What should be the role of natural plant succession in land rehabilitation?

4. In some cases it takes years to get approval from lead agencies involved with surface mining and reclamation ordinances to initiate reclamation.

5. Too many different local, State, and Federal agencies are involved with surface mining and reclamation ordinances.

6. The Federal government should learn from the results of the deregulation of the airlines. When governmental controls were released and free competition based on service and price were allowed to fluorish service improved and cost decreased. I hope the same principles can eventually be shown to apply to all industry and you and I as consumers will make our wills felt directly by our purchasing power rather than indirectly through Federal regulations, which in the past have proved costly (in terms of inflation) and in many cases contradictory.

7. We need the capability to evaluate mining and reclamation plans (operating plans), whatever the commodity, in the context of what is presently there, how surface protection can best be accomplished, and what can be expected as a reclaimed surface. We have found, many times, that data accumulation lists lead to excessive, expensive reports which do not always lead to better informed decisions or appropriate mitigation because these data are beyond the present capability to interpret and utilize.

8. Any list of the "most important environmental problems" associated with minerals other than coal depends upon "the eyes of the beholder," i.e., his or her personal understanding of National needs, technology, and a host of other factors.

9. The finding of a suitable end use for a land disturbed by mining, bearing in mind the possible potential adverse environmental problems resident in these sites.

10. The most important environmental problem (in Alaska) continues to be inflexible Federal regulations promulgated to solve midlatitude problems, which when applied in Alaska demand unrealistic or environmentally unsound practice. For example, certain regulations based on "best technique" in Kentucky or Wyoming, would result in intolerable environmental damage if applied in areas of permafrost. We urge that your NAS team arrange for testimony

specific to Alaska as a part of its study of noncoal mining and reclamation practices. It is imperative that any nationally applicable laws recognize the unique environments to which they may be applied with counterproductive results. It is far easier to have necessary exceptions written into a proposal than to attempt remediation of regulations already promulgated.

11. Long-term quarries and pits have difficulty in getting a bond for commercial carriers for periods of time past 10 years.

12. In Iowa, we are aware of our problems and of the environmental problems created by the surface mines of various kinds. We are meeting those problems. When the Congress passed P.L. 95-87 and attempted to find all the problems across the Nation with all its various climatic conditions, mining techniques, kinds of overburden, etc., that put us all under the same large bureaucratic umbrella; then the problems really began.

13. Some of the problems connected with surface mining and reclamation are not technological problems at all, but nevertheless are considered serious problems in the overall context of how surface mining fits into or dovetails with the overall environmental picture or just plain wise use of the land.

14. Criteria for release of reclaimed land should be spelled out in general, practical, utilitarian terms, insofar as practical, rather than in technological, engineering type terms.

15. The state of the art (in erosion prevention, revegetation) is basically satisfactory but most of the trouble lies in finding enough adequately trained personnel and a willingness on the part of the mining companies to spend sufficient money to do the job.

16. Failure to recognize the total reclamation process and possibilities in order to reach a desirable predetermined end result.

B. Effects of Climate and Geography on Mitigation Efforts

1. How to obtain plant establishment on disturbed arid sites.

2. Violent or extra strong wind storms can be extremely devastating to revegetation or tailings.

3. In the Southwest, our principal problem in reclamation is the difficult coincidence of overburden substrates which are often saline in an area where rainfall is low, sporadic, and unpredictable.

4. In the Great Basin, mines are found at a variety of elevations and latitudes. Each site requires different solutions and there are relatively few pat answers.

5. Management of plant transpiration to promote survival of shrub and tree planting stock on bentonite and uranium spoils in northern Great Plains and/or research to determine adaptability.

6. The above problem is due to the lack of knowledge to manage the wind and temperature which promotes desiccation and/or could be used to advantage such as distribution of snow for added moisture.

7. The inability to effectively revegetate exposed mining properties (road surface, tailings dams, and spoil piles) in desert or chaparral areas due to lack of consistent rainfall and fertile soil leads to high levels of suspended solids entering receiving streams. In some cases these solids, upon settling, have covered natural stream substrates in Arizona streams as high as 0.2 m. The effect of the tailings cover is to eliminate burrowing and benthic invertebrates and to displace fish populations to less polluted areas; only migratory and adventitious species remain.

8. In north latitudes climatic constraints are of prime concern. It is necessary to determine species with adaptability for the climatic regime.

9. Alpine mine rehabilitation (general).

10. Rehabilitation of Nevada barite mines in an extremely arid environment.

11. Reclamation of arid and sodic lands. Two areas that immediately come to mind are reclamation of potential uranium mines in the Pryor Mountains where annual rainfall is as low as 6 inches, and the reclamation of bentonite areas.

12. Revegetation of tailings areas and dumps at high altitude - base metal and uranium mining.

13. Another factor which creates a potential environmental problem is an appreciable rainfall so that the operation cannot proceed without a net effluent.

14. The potential effects on the subalpine environment and identification of mitigating measures.

C. Problems of Erosion and Topography

1. Building or construction materials--this may be part esthetic but revegetation of open vertical rock faces (of ever increasing abundance) is not possible.

2. Prevention of downstream erosion of soil material. It is essential that all aspects of mining ventures be done so as to reduce soil movement into watersheds.

3. Prevention of increased surface water in downstream watersheds. Greatly increased stream flow results in soil movement and alteration of the life support system in streams and rivers.

4. Mountain hard rock mines--reclamation a problem due to mine age, lack of surface soil, and acid drainage.

5. Mass instability of mine wastes whenever they are piled on steep slopes.

6. It is completely impossible to eliminate all sedimentation and appreciably more difficult to reclaim and vegetate steep mountain sides of quarries. In many cases, the ore was bare rock with no topsoil or vegetation on it at the time we initiated ore mining activities. Our results differ very little from the state nature had developed in these instances when we started our mining operation.

7. Formation of highly turbid water in impoundments left after strip mining bentonite clay in the northern Great Plains and lack of information of specific erodibility factors for the soil and geologic conditions present that are needed to efficiently control the turbidity problem.

8. Mine spoil continually washing into streams especially during winter and spring rains.

9. High walls on the phosphate mines and how to rehabilitate them.

10. A potential problem is the high wall left by many mining operations. It is feasible, however, to eliminate the high wall upon completion of operation by setting off charges at different intervals creating a slope.

11. The effects of silt on streams which must meet the NPDES criteria for discharge.

12. Sloping of high wall--preregulated quarries which have high walls common to those high walls standing prior to the law.

13. Surface stability of the materials and overburden in temporary storage during the active mining operation and that of the recontoured site following reclamation: In this regard provision for the stable storage of large quantities of clay bearing overburden materials on steep contours west of the Cascades and the stabilization of these same materials to allow revegetation of the reclaimed area constitute perhaps the major problems for the rock and aggregate mining sites in that area.

14. Management of excessive amounts of surface water which result from the rainfall which averages from 40 to as much as 200 inches of rain per year and even more in some sections of this portion of Oregon. This amount of surface water coupled with the large amounts of clay from the weathered marine basalts and the lateritic soils pose real problems in maintaining water quality in the State's stream courses in areas near any mining areas.

15. In the eastern part of Oregon the problem is equal but opposite. The arid climate and silty clay loam soils combine with periods of high wind and sudden deluges and flash floods pose unique surface stability problems both during the mining operation and for the site during reclamation.

16. High walled hardrock mines. Every quarry, including rock-borrow quarries along Vermont's system of interstate highways has been left with high walls containing loose, unscaled material. These quarries are not only esthetically unpleasing but are also safety hazards for unwary rock hounds, etc.

17. High walls from clay mining.

18. Blowing tailings-base metal and uranium mining.

19. Seepage and tailing dam stabilities are environmental factors to consider in design and operations.

20. Techniques for containing the effects of erosion and sedimentation to permitted lands so that contiguous watersheds will not be adversely affected is a most important issue.

21. Exposed sides of open pit metal mines contaminate snow and water with metallic ions. This water drains through geological fractured material depositing high concentrations of metallic ions into streams.

22. Sediment discharge into stream from mining areas prior to dump stabilization.

D. Soils, Spoils, and Tailings

1. Nutrient mobility and moisture are severely restricted in spoils that are colloidal in texture and extremely high to sodium salts. Because of this condition, large areas of rangeland which have been mined for bentonite are nonproductive in terms of revegetation.

2. Any accumulation of heavy metals in the soil, particularly the copper smelter plume field and tailings pile. Arid and stress environments are most critically affected. Also heavy metals leached into stream (total impact unknown) and airborne.

3. Difficulty in establishing vegetation on mine spoils because of extreme rockiness, low pH, and toxicity of spoil material.

4. Oil shale reclamation similar to bentonite-stress environment.

5. Mine waste dumps. In Vermont great waste piles exist at the sites of our granite, marble, asbestos, and slate mines.

6. Iron and copper tailings basins also present problems. Sometimes due to acidic content, they can be inimical to life but more often they simply will not support life because of the absence of any life-promoting nutrients.

7. High on the list is the problem of the acid generating nature of sulfidic tailings.

8. The most serious problem is tailings from metal mine milling operations. The texture, chemistry, and structure of these areas are by far, in my opinion, the most serious problems in all of reclamation.

9. Kiln dust piles or agricultural lime piles. The vegetation of the kiln dust piles is difficult because the material is highly basic and contains almost no essential nutrients. The ag lime piles are product but the manufacture far exceeds the demand. As a result, large piles remain. In addition the companies do not want to stabilize these piles because they wish to sell the product.

10. Disposal of mine wastes and tailings--Montana's Hard Rock and Open Cut Mining Acts do not require backfilling and have weak provisions regarding the approximate original contour.

11. Methods of dealing with excessive amounts of molybdenum or selenium in soils either occurring naturally in association with uranium deposits, or as an aftereffect of mining.

12. Tailings stability and integrity.

13. Mass movement of material from unstable mine dumps.

14. Blowing uranium tailings.

E. Revegetation

1. Achievement of rapid revegetation of all disturbed areas. (Vegetative cover is a primary tool in the effort to prevent erosion and runoff.)

2. Inability to revegetate mine spoils because of continuous mining operations.

3. Knowledge is lacking on species (forbs and shrubs) requirement necessary for propagation and establishment on relatively inert bentonite clay and uranium spoils on the northern Great Plains. This is particularly true in regard to the needs for endo- and ectomycorrhiza.

4. Information is still lacking on site amelioration for establishment of shrubs on bentonite and uranium mine spoils on the northern Great Plains.

5. Slow process of release of plant materials to the commercial market by the agencies that have been involved in their selection and development. It seems that many varietal release committees are reluctant to put a variety of proven performers of "native" species out to commercial production as a standard.

6. The growers and collectors of the range type species that are in demand today for reclamation work cannot keep up with the quantities of seed required for the areas that are requiring treatment.

7. Inability to revegetate water impoundments left after strip mining bentonite clay in the northern Great Plains with aquatic and wet meadow species due to lack of information on appropriate techniques and species.

8. Difficulty in establishing plant stand due to inadequate moisture.

9. Establishment of normal microflora (saprophytes, nitrogen fixers, and mycorrhizal symbionts) in spoil material.

10. A major problem relates to the "availability of plant materials" that are (1) adaptable to a range of severe site conditions, and (2) are acceptable by society. Three critical site conditions in order of priority are (1) seedling desiccation (drought, low temperatures); (2) biological damage (rodents, big game); and (3) management. The problems of "socially acceptable plant materials" relate to (1) current limits of law and its interpretation, (2) realistic "planned land uses," (3) the conflicts of highly desirable native species vs. "undesirable" native species, (4) unknown responses of "introduced species."

11. Dieback problems within 3 years on revegetated, abandoned manganese and iron ore mines.

12. Revegetation and stabilization in open pit mining of base metals.

13. The overburden in certain areas contains low-grade oil sands whose relatively low bitumen content does not merit extraction. Such areas are difficult to revegetate as some components of the bitumen in these overburdens are thought to be toxic to plants in some stages.

14. The tailings sand left after the oil has been extracted is extremely deficient in plant nutrients, and it is also generally poor in microbiological activity. Although the sand may be readily revegetated if amended with peat, it requires yearly fertilization to maintain a healthy plant cover.

15. Serious problems are associated with attempts to revegetate extensive acidic or otherwise toxic tailings in the absence of sufficient quantities of topsoil.

16. Bentonite clay pots (in Wyoming) become coated with glauber salt. Revegetation of these extremely high sodium areas is difficult.

17. A problem exists in establishing vegetation on alkaline soils.

18. A problem exists as to the vegetation of sediment and/or tailings ponds which are so unstable as to not allow even access by foot.

19. Revegetation of lateritic soils in Oregon poses a significant problem for the large-scale nickel mining operations as well as other proposed mining operations.

20. Fairly large-scale mining operations are either presently being conducted or are planned for diatomaceous and bentonitic materials. Only a minimum of upper horizon growth media material exists in these areas prior to mining and vegetation is sparse at best. The reclamation of these particularly sterile areas poses some unique problems which need to be addressed since these areas are subject to heavy sudden downpours, flash flooding, and strong wind erosion.

21. The rock piles of the iron mines are in some cases already 600 ft high with estimates of their reaching 1,000 ft. The individual rock fragments are from inches to feet in diameter with no overburden covering. It is impossible to provide a vegetative cover on a pile such as this, without special procedures.

22. Reclamation of hard rock mines where little, if any, salvageable soil material exists prior to mining.

23. Revegetating and stabilizing slopes containing sterile soils.

24. A problem of particularly serious importance to Colorado is plant materials suitable for revegetation above 11,000 ft. At present, about the only way to revegetate such areas back to natural conditions is saving vegetation and transplanting it. Some progress has been made in developing native seed for alpine tundra revegetation, but supplies are extremely limited and almost prohibitively expensive.

25. The determination, evaluation, and use of species with tolerant (to disturbed sites) ecotypes would substantially further the revegetation effort.

26. Utilization of a plant breeding program to make available plant lines that are adapted to the severe selection pressures on disturbed mine sites.

F. Water Pollution and Hydrological Effects

1. Solution mining and restoration of the hydrologic regime.

2. There is concern that as more mines are developed the regional hydrology may be significantly altered.

3. Tailings are frequently of such great volume as to seriously interfere with local hydrologic resources, both in terms of drainage patterns and degradation of water quality.

4. The most important environmental problems associated with copper and uranium mining and milling is the result of these metals entering streams and into the ground waters from waste dumps and tailing ponds.

5. Dewatering--the effects of dewatering quarries, pits, etc., on adjacent private and public water supplies.

6. Cyanide and stream siltation problems related to cyanide heap leaching processes.

7. Formation of fine silt ponds or lakes from the washing and refining operation of the phosphate sand, dirt, or muck. This is a very serious problem because many or most of these very fine silt or "slime" ponds or lakes will not settle or harden enough to bear the weight of cattle, machinery, etc., for many years or sometimes, apparently, indefinitely. Thus, this mining is causing a type of pollution or "waste land" at the same time that reclamation is restoring the mined-over land to useful use again.

8. Mine drainage and quarry ponds.

   a. Acid mine drainage is an environmental problem in so far as nearby surface streams are concerned.

   b. Quarry ponds are often attractive hazards in that they encourage unsupervised swimming in a hazardous environment.

9. Excess number of ponds left from sand and gravel operations.

10. Disruption of river channels from sand and gravel operations.

11. Locally, heavy metals entering surface waters. This problem may also exist relative to ground water but no definitive studies have been conducted as yet.

12. Water contamination from both tailings and mines - base metals and uranium mining.

13. Lakes created by alluvial sand and gravel operations result in large evaporative losses from the stream system.

14. Surface and ground water contamination of aquifer and stream systems is the largest environmental impact potentially resulting from noncoal mining operations.

15. Water supply and demand estimates in one of the major mining areas generally were of low quality.

16. The use of the aquifer of nearby streams for process water often lowers the water table which in turn reduces surface flow. This problem is critical in the Southwest where most streams are naturally of low volume. There are instances where water withdrawal for ore processing have essentially "dried up" streams that prior to mining activities supported abundant aquatic life (in some cases endemic fishes). This destruction of stream habitat is usually irreversible due to the low recharge rate of the aquifer. As a result, the only times of surface flow are during periods of high runoff from rains or snowmelt.

17. Consumptive water--use changing both quality and quantity.

18. Aquifer bridging by exploratory drilling.

19. A most important environmental issue concerning surface mining is the problems that arise from poorly conceived surface mining such as: pollution of soils and watersheds by chemical erosion.

20. Abandoned mine portals continually drain acid mine water, high in metal ions, into streams.

21. Dust from oxidized chalcopyrite, coballite, pyrite, and phorholite minerals collecting in snowpack is extremely harmful to all aquatic organisms.

22. There is no EPA standard for uranium in drinking water.

G. Air Quality

1. Need to develop some air quality standards that are more realistic than those currently used. The current standards have not adequately stated the basis on which they have been promulgated and have shortcomings in not adequately allowing for the fact that all environments can withstand increased levels of particulates for greater periods than allowed; the amount of particulate removal specified does not distinguish between effects of small and large particulates.

2. Particulate emissions to the environment from all types of mining.

3. Power now generated for the bitumen extraction and the upgrading process results in several hundred tons of sulfur (as SO_2) and other airborne pollutants being emitted into the atmosphere every day. Concern is being widely expressed about the eventual detrimental effects of these pollutants on wildlife, forest productivity, streams and lakes, and soils in the region, especially as more mines are developed.

4. Handling of mining operation particulates (fugitive dusts, vehicle emissions, other industrial particulates, and SO_2) in light of the 1977 Clean Air Act requirements.

5. Reclamation of some gold placer tailings both in stream and river beds and at sites of high bars may *not* result in a best use, as the disturbed channels provide ponds which enhance fish and wildlife habitat.

6. A serious problem is the contamination of local air due to the conveyance of airborne particulates due to blowing of unvegetated, active mine tailings.

7. The most significant impact that comes to mind is the presence of uranium particles in the smoke from phosphate smelters. Uranium is frequently found in minute quantities in the same formations in which phosphate ore occurs.

H. Fish and Wildlife

1. The wildlife data generally available are of low quality.

2. What makes a suitable wildlife habitat in rehabilitating disturbed lands?

3. The effects of discharges containing potentially toxic metal ions on aquatic life in streams are often hard to substantiate. Other than fish kills, the effects of heavy metals on the stream biota are not as immediate or distinct as those of settled suspended oslids. Contaminated streams continue to support aquatic life despite sporadic fish kills; however, the biological condition of these populations remains largely unknown. Evidence of metal bioaccumulation in resident species may suggest that possible detrimental effects may be manifested in the future.

4. The tailings ponds contain oil scums which are a hazard to wildlife, especially migrating waterfowl. There also is some concern that streams and rivers could be polluted with oil, heavy metals, sediments (sludges), and salts from the tailings ponds if the dikes should fail. Leaching of hydrocarbons, salts, and heavy metals from the tailings pond into the ground cover system is another area of concern.

5. The entire problem of alteration of water quality is problematic. As anadromadous fish are a prime resource to be protected in Alaska, we are very concerned over any changes in water quality, especially trace element abundance, which are apparently the homing beacons used during spawning runs. It would appear that any alteration of natural waters may be damaging: whether by introduction of "pollutants" or by "cleaning up," through neutralization or clarification regulations. However, the limits and impacts are poorly known, especially for the changes made by "cleaning up" waters in a naturally acidophyllic palludal environment. We hope to be able to arrange for such a study in the near future.

6. Sand and gravel or placer operations located near spawning areas are of particular concern.

7. Lakes created by alluvial sand and gravel operations are generally good for waterfowl and aquatic species.

8. Habitat destruction occurs through stream rechannelization and altered flood drainage caused by some sand and gravel operations.

9. Need to identify the actual effect of minerals development on threatened and endangered species and other wildlife.

10. The methods in which mining takes place in some areas resulting in highways have caused a significant delay in elk and deer reaching their winter ranges.

11. Mining activity often causes adverse impacts on wildlife other than big game due to increase in activity, access, and numbers of people in the back country.

12. Mining often results in destruction of *mature* wildlife habitat which even the best reclamation efforts cannot replace.

13. Often, reclamation efforts are not designed to benefit wildlife habitat.

14. The surface mining of oil shale and the subsequent impact on wildlife are of major concern.

I. Abandoned Mines

1. Rehabilitation of abandoned placer operations.

2. Abandoned small mine rehabilitation.

3. Blowing mill tailings from abandoned (copper) mines are an irritant to nearby settlements and a source of toxic metals entering streams.

4. Revegetation of old clay spoil dumps where topsoil is sparse. This is a very difficult problem. Without use of adequate topsoil (sometimes very hard to obtain) successful revegetation of old "orphan" (mined before the law) mine dumps has proved most difficult. Additional research is needed here.

5. Acid mine drainage and heavy metal problems from abandoned mines.

6. We feel that since the implementation of the Act we can maintain enough control over the active sites to prevent future environmental problems. However, the abandoned operations present several problems. The sand/gravel pits often have considerable erosion. There is little nutrient or organic content of the base material.

7. Most adverse environmental effects from mining areas are usually attributable to the abandoned mines for which no public funds are available for their solution.

8. Abandoned copper mine tailings. Vermont's copper mining ceased in 1955 and large tailings dumps are still sterile deserts 24 years later. Leaching causes pollution of both surface and ground waters in the area.

9. Stone quarries present a problem. In almost all abandoned quarries there is no hope of revegetation. Also, many old quarries were left with vertical high walls, thus presenting a safety hazard.

10. Seepage from abandoned pits of low pH water into local streams.

11. Dormant uranium mill tailings piles which are not stabilized according to the stringent specifications which apply to active mine and mill sites. Surface water, ground water, and air contamination result.

J. Research Problems and Needs

1. Problems in research methodology such as: subsequent rapidly inflating prices, particularly for energy, made results of some analyses unrealistic.

2. Research needed before we can assure success of revegetation on metal mine reclamation sites in Great Basin.

3. The following is a list of high priority needed studies:

   a. Methods to predict potential ground water pollution from mining operations.

   b. Methods to protect the ground water from seepage from tailings disposal areas.

   c. Methods to control erosion and sediment discharges from all types of mining.

   d. Environmentally safe methods of solid waste handling and disposal.

   e. Reclamation of mining waste under adverse conditions, e.g., arid conditions, and high altitude.

   f. Dust and noise control for mines near population centers, e.g., sand and gravel.

   g. Thickness of earth cover over toxic materials to prevent surface and ground water pollution and promote vegetation.

   h. Maximize recycle and reuse of water in mining operations.

   i. Methods to "close down" underground mines so that they do not create environmental problems at a later date.

   j. Methods to control pollution from the inactive underground mines.

4. In both Montana and Wyoming, there are considerable bentonite orphan spoils. Because Federal funds are now available for reclamation expenditures concerning these lands, it is unfortunate that only little effective research has been done to make feasible use of the available funding.

5. The disposition of radioactive or hazardous metal mine tailings, mill processing by-products, and low grade ore needs to receive much study. We have had a history of uranium mining and milling in Oregon and at the present time there is a potential for further large scale mining operations in southeastern Oregon involving both radioactive materials and mercury ore.

6. Studies on various plant species adaptability on surface mine spoils and waste piles.

7. Establishment of microbial populations in mine spoils and waste piles.

8. Performance of individual species in various grass mixtures growing on mine overburden piles.

9. Studies in heavy metals uptake by various plants and its effects on livestock and wildlife.

10. Vertical mulching as a treatment for improving infiltration in bentonite and high clay soils.

K. Other Effects

1. Blasting - the effects of blasting on water supplies and adjacent structures.

2. Mining roads - for many hard rock mines (in Montana) the acreage disturbed by road construction approaches or exceeds that disturbed by the mine and associated facilities. Furthermore, mine roads, despite existing reclamation requirements, continue to be used by hunters, recreationists, and others upon abandonment.

3. Hit-and-run sand and gravel operators who extract gravel for a few days without a permit and then move on.

4. Radiation confinement in the uranium mining industry.

5. Hydrologic and esthetic problems associated with access and haul roads in mountains and other scenic areas.

6. Random emissions from stabilized uranium mine tailings and from reclaimed mines.

7. The social effects on small communities.

8. The economic effects of development vs. nondevelopment on local, regional, and national bases.

9. Large areas disturbed by mining exploration where suitable reclamation methods are not applied immediately after disturbance. This includes all types of minerals especially in high altitudes.

10. Potential toxic plants growing on mine spoils and waste piles.

11. Potential hazards of low-level radiation are underestimated.

12. Plants growing on uranium tailings can take up radon.

13. There exists a potential of selenium poisoning through aquifer contamination by drilling.

14. There exist health hazards associated with uranium mining (i.e., lung cancer).

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E16	W. C. Ackerman, Dep. Environ. Protec., Wyoming
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B5, B6, E3, E4	A. Bjugsted, USDA Forest Service, Rocky Mt. For. and Range Exp. Stn.
E5, E6	R. Brammer, Randall and Blake, Inc.
G7	E. R. Burroughs, Jr., USDA Forest Service, Intermt. For. and Range Exp. Stn.
B12, C17, C18, F9, F10, F12, J3	B. Campbell, Dep. Nat. Resour., Colorado
D7, E8, E23, F11	B. L. Cole, Comm. of Public Lands, Washington
B13, C19, D7	R. L. Coleman, Noranda Mines Ltd.
C8, E11	J. F. Corliss, USDA Forest Service, Region 8
C20	S. Darby, Dep. Nat. Resour., Georgia
A16, B10, C5, E4, E18, J5	G. Davis, SEAM Program, USDA Forest Service
C1, C4, D2, D4	L. E. Eddleman, Univ. Montana
C2, C3, D3, E1, E2	R. B. Ferguson, USDA Forest Service, Intermt. For. and Range Exp. Stn.
F15, H1, J1	J. R. Gray, New Mexico State
A10, F4	R. L. Harris, USDA Forest Service, Region 3
C7, E7	C. L. Hawkes, USDA Forest Service, Rocky Mt. For. and Range Exp. Stn.
B11, D10, E22, F6, I5, K2	B. Hayden, Dep. of State Lands, Montana
E24	M. Heifner, Dep. Nat. Resour., Colorado
J3	R. Hill, U.S. Environmental Protection Agency
J4	R. Hodder, Montana State Univ.
D8, G5, I3	C. M. Hofferber, USDA Forest Service, Region 6
D8, F13, H6, H7, H8, I11	D. Holm, Dep. Nat. Resour., Colorado

G1	W. A. Hunt, Mont. State Univ.
A8	J. E. Jinks, U.S. Dep. Environ., Bureau of Mines
B9, B10, C9, D7, G4, I1, I2	W. L. Johnson, USDA Forest Service, Region 4
E12, F1, G2, J4	F. T. Klinge, Ford Bacon & Davis, Inc.
B14, H9, K7, K8	B. C. LaMoure, USDA Forest Service, Region 1
E8, E9	D. Lindsey, New Mexico State Univ.
C10, E17, E18	O. W. Lineberg, Div. of Mined Land Reclam., Virginia
B7, F16, H3	M. A. Lewis, Proctor and Gamble Co.
K6	Wm. A. Lochstet, Penn State Univ.
A13, A14, A15, F7, I4	C. C. McCall, Dep. of Conserv., Tennessee
A1, A2, A3, B1, H2	C. M. McKell, Inst. for Land Rehab.
H10, H11, H12, H13	A. Mehroff, U.S. Fish and Wildlife Serv., Boise, Idaho
B8	W. W. Mitchell, Univ. Alaska
E15, F3	R. T. Moore, ERT Ecological Consult., Inc.
I10	G. Newsom, Dep. Pollution Control and Ecology, Arkansas
D11	V. H. Newsom, Surface Mining and Reclam., Texas
F19, H14	S. J. Packer-Moore, Sierra Club
F14, G6	P. S. O'Boyle, Eng. Geologist, Colorado
I7	W. Padgett, Dep. of Mines, Oklahoma
A9, D7	T. H. Peters, Inco Metals Co.
B3	L. D. Potter, Univ. New Mexico
E25, E26	P. Pratt, Range Dep., Utah State Univ.
C16, D5, F8, I8	C. A. Ratte, State Geologist, Vermont
C21, F20, F21, J6, J7, J8, J9, J10, C22, D13	B. Z. Richardson, USDA Forest Service, Intermt. For. and Range Exp. Stn.
A4, A5	D. Reining, Calif. Rock Products Assoc.
D6, D9, E21	R. Reszka, Dep. Nat. Resour., Michigan
C6	C. P. Rogers, Jr., The Feldspar Corp.
A6	R. J. Roman, Industrial Minerals Prod.

A12	M. B. Ross, Mines and Mineral Div., Iowa
A7	R. L. Sanks, Dep. Civil Eng., Montana State Univ.
H5	R. B. Sanders, Dep. Nat. Resour., Alaska
A7	T. E. Schessler, USDA Forest Service, Region 2
I6, I9	T. Schmidt, Dep. Nat. Resour., Maryland
E10	S. Stranathan, Upper Colorado Environmental Plant Center
E13, E14, F2, G3, H4	S. K. Takyi, Alberta Energy and Nat. Resour.
A11, C11, C12, F5, K1	D. R. Thompson, Dep. Environ. Resour., Pennsylvania
B2, B4, J2	P. T. Tueller, Univ. Nevada
D1	T. Yamamoto, USDA Forest Service, Rocky Mt. For. and Range Exp. Stn.

SECTION II. BIBLIOGRAPHY

A. Bibliographies and Comprehensive Texts

Citations included in section A are those bibliographies dealing primarily with surface mine reclamation, potential solutions to surface mining impacts, and texts dealing with the same subjects. It is not possible to abstract such a section, but most of the important citations from the bibliographies appear elsewhere in this document. They are cited primarily to give weight to major concerns and are referenced by impacts in the index.

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B. Current Research and Papers

Citations in section B were selected from the following sources: (1) Current research as described in responses to the survey inquiry letter. (2) Current papers (in press and unpublished reports) obtained from responses to survey letter. (3) Citations from file 60, "Current Research Information" (Lockheed "Dialog"). (4) Citations from data file, "Research in Progress" (RECON data vendor). The citations are grouped in the index by subject matter and/or impacts.

95. Archer, V. E., E. Radford, and O. Axelson.
1978. Radon daughters cancer in man. Presented to the Health Physics Society, June 19-23, 1978. (unpubl.)

96. Armiger, W. J.
1979. Revegetation of surface mined areas. Beltsville, Md.

97. Berg, W. A.
n.d. Vegetative stabilization of Paraho spent oil shale. (A mathematical model of salt and water transport.) Colo. State Univ., Fort Collins.

98. Berg, W. A.
n.d. Vegetative stabilization of spent oil shale. (Field studies involving establishment and the monitoring of native plant cover.) Colo. State Univ., Fort Collins.

99. Bjugsted, A. J.
n.d. Adaptability of selected tree and shrub species on bentonite mine spoils, Crook County, Wyoming and Butte County, South Dakota. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

100. Bjugsted, A. J.
n.d. Basin morphometry of strip mine ponds compared to stock ponds in the northern Great Plains. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

101. Bjugsted, A. J.
n.d. Influence of small mammals in the rehabilitation of areas disturbed during open pit mining. South Dakota Sch. Mines and Technol., Rapid City.

102. Bjusted, A. J.
n.d. Invertebrate species, abundance and standing crop biomass in strip mine ponds compared to stock ponds in the northern Great Plains. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

103. Bjugsted, A. J.
n.d. Nongame bird habitat associated with mine haul roads and surface mining for bentonite clay. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

104. Bjugsted, A. J.
n.d. Survival and growth of containerized vs. bare root shrub and tree planting stock on bentonite spoils in northeastern Wyoming. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

105. Bjugsted, A. J.
n.d. The synthesis of information to develop guidelines for managing strip mine water impoundments. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

106. Bjugsted, A. J.
n.d. Time trend changes in physiochemical properties of emplaced bentonite mine spoils near Colony, Wyoming. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

107. Bjugsted, A. J.
n.d. Water quality in strip mine ponds compared to stock ponds in the northern Great Plains. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

108. Bjugsted, A. J.
n.d. Waterfowl use of water impoundments left by strip mining in the northern High Plains. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

109. Brown, R. W.
1979. Revegetation of disturbed alpine tundra rangelands. (Abstr.) 32nd Annu. Meet., Soc. Range Manage., Casper, Wyo. p. 20.

110. Brown, R. W.
n.d. Effect of different revegetation techniques on successional trends on mine spoils. Utah State Univ., Logan.

111. Brown, R. W., T. Box, and P. Howard.
n.d. Evaluation of mining and post mining management on plant succession in natural ecosystems. Utah State Univ., Logan.

112. Carroll, R. E.
n.d. Wildlife and wildlife habitat survey - Glasgow. Ecological Consulting Service, Helena, Mont. [Baseline ecological survey including bentonite mined areas.]

113. Carroll, R. E.
n.d. Wildlife and wildlife habitat survey - Malta. Ecological Consulting Service, Helena, Mont. [Baseline ecological survey for bentonite mining areas.]

114. Chappell, W. R.
n.d. Toxic trace elements associated with shale oil production. Colo. State Univ., Boulder.

115. Costello, J.
n.d. Mortality of metal miners in the United States. Natl. Inst. for Occupational Safety and Health, Rockville, Md. [A survey and study of occupational health hazards relating to metal miners.]

116. Dean, K., and R. Davis.
1971. Vegetative stabilization of mill tailings using municipal and mineral wastes. Paper presented at the Environmental Quality Conference for the Extractive Industries, AIME [Washington, D.C., June 7-9, 1971].

117. Dean, K. C., and R. Havens.
1972. Reclamation of mineral milling wastes. Paper presented at the Annu. AIME Meeting [San Franciso, Calif., Feb. 21-24, 1972].

118. Dean, K. C., R. Havens, and E. G. Jaldez.
1970. Progress in using and stabilization of mineral wastes. Paper presented at the AIME Meeting [St. Louis, Mo., Oct. 21-23, 1970].

119. Dudley, R. F.
n.d. Machinery for establishment and maintenance of pasture and hay land in the East. Crop Production Engineering, Beltsville, Md. [Special machinery has been developed for deep placement of soil amendments into mine spoil banks.]

120. Eddleman, L. E.
n.d. Regeneration of indigenous species including germination and establishment in stress environments. Univ. Mont., Missoula.

121. Eddleman, L., and P. L. Meinhardt.
[In press.] Seed viability and seedling vigor in selected prairie plants. In Proc. 6th North Am. Prairie Conf. [Ohio State Univ., Columbus, Aug. 13-16, 1978].

122. Eno, C. F.
n.d. Preliminary non-projected research in soils. Univ. Florida, Gainesville. [Experiments were initiated to study three facets of reclamation: (1) slime dewatering by evapotranspiration, (2) amendment and fertilization of dry slime, and (3) amendment and fertilization of sand tailings. Results indicate successful reclamation of sand tailings by addition of dry slime (colloidal phosphate), sewage sludge, and fertilizers.]

123. Farmer, E. E., and B. Z. Richardson.
n.d. Performance of individual species in various grass mixtures growing on mine (Montana coal, Idaho phosphate and Idaho heavy metal) overburden piles. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

124. Farmer, E. E., and B. Z. Richardson.
n.d. Snowpack influences on acid mine drainage (in the West). USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

125. Farmer, E. E., B. Z. Richardson, and P. E. Packer.
n.d. Effect of revegetation on acid production within a mine overburden. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

126. Ferguson, R. B.
n.d. Evaluation of copper tolerant clones of *Agrostis* spp. on spoil areas at the Kennecott copper mine in central Utah. USDA For. Serv., Intermt. For. and Range Exp. Stn., Provo, Utah.

127. Ferguson, R. B., S. B. Monson, and P. Grubaugh.
n.d. Plant species adaptability trials on copper mine spoils in central Utah (Kennecott). USDA For. Serv., Intermt. For. and Range Exp. Stn., Provo, Utah.

128. Frischknecht, N. C., R. B. Ferguson, and P. E. Packer.
n.d. Develop recommendations, guidelines, and criteria for revegetation of coal and oil shale spoils on semi-arid lands. USDA For. Serv., Intermt. For. and Range Exp. Stn., Provo, Utah.

129. Ford, Bacon, and Davis, Inc.
n.d. Evaluation of radiation contamination from various sources and alternative disposal possibilities for the confinement of radiological wastes. Salt Lake City, Utah.

130. Galloway, W. E.
n.d. Predicting response of a natural system to uranium extraction, Oakville aquifer system, Texas. Tex. Univ., Austin.

131. Harvey, S., and T. Weaver.
1979. Reproductive biology of four *Artemisia* species with emphasis on revegetation. (In rough draft form.) Mont. State Univ., Bozeman.

132. Hawkes, C. L.
n.d. Selected literature related to aquatic impoundments on semi-arid regions: an annotated bibliography providing a basis for designing and managing American Northern Great Plains strip mine ponds for aquatic habitats and agricultural use. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

133. Hawkes, C. L.
n.d. A survey of the aquatic habitat of existing coal and bentonite clay strip mine ponds in the northern Great Plains: a basis for design and management decisions: an overview. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

134. Hawkes, C. L., and M. T. Anderson.
n.d. Water quality of 43 selected northern Great Plains impoundments including coal, bentonite clay strip mine ponds, and livestock ponds. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

135. Henry, C. D.
n.d. Trace and potentially toxic elements associated with uranium deposits of South Texas. Texas Univ., Austin.

136. Hughes, H., and Associates.
1966. Feasiblity report, channel improvement and erosion control, Railroad and Copper Creeks, vicinity of Holden Village, January 28, 1966. 22 p. H. Hughes and Associates. An "open file" report to USDA For. Serv., Wenatchee, Natl. Forest, Wenatchee, Wash.

137. Hunt, W. A., and D. Cowger.
1977. Program development for measurement of erodibility of spoil banks and untreated topsoil due to wind action. Unpubl. rep., USDA For. Serv., Intermt. For. and Range Exp. Stn., Bozeman, Mont.

138. International Minerals and Chemical Corporation.
1978. Water management in phosphate mining at IMC, Lakeland, Florida. Unpubl. rep. 20 p. Int. Min. and Chem. Corp., Lakeland, Fla. [Water management and conservation are important goals of this corporation. Water use is preplanned. The concepts of water recirculation, zero net withdrawal from the Floridan Aquifer, controlled surface runoff, superior flood control, zero process discharge, and water cropping are explained. Many of these are goals of the corporation and incorporated into their water management plan.]

139. Jurgensen, M. F.
n.d. Microorganisms of inoculated rhizosphere soil on copper mine tailings. Mich. Tech. Univ., Houghton.

140. Kennington, G. S., and J. E. Doerges.
n.d. Report on bioassays of radium-226 uptake in selected plants and animals at the Highland Uranium Mine, Wyo. Wyo. Dep. Environ. Qual.

141. Landa, E. R.
1978. The migration of radionuclides for uranium mill tailings - earth science perspectives. Unpubl. rep., Uranium Information Network.

142. Lewis, M. A.
n.d. Selected heavy metals in sediments and biota from desert streams of the Gila River drainage (Arizona). Proctor and Gamble Co.

143. Lindsey, D.
n.d. Development of techniques to establish mycorrhizal associations with plants used to revegetate strip-mined lands. N.Mex. State Univ., Las Cruces. [This association, in a number of cases, has increased growth and survival of plants on disturbed areas.]

144. Linder, R., and T. Schard.
n.d. Non-game bird habitat associated with haul roads and surface mining for bentonite clay. S.Dak. State Univ., Brookings.

145. Lochstet, W. A.
1979. An analysis of the proposed White Mesa uranium project. Unpubl. rep., Feb. 1979, to the Nuclear Regulatory Commission.

146. Ludeman, W. W.
n.d. Study plan for use of wood residue soil amendments for reclamation of bentonite mine spoils in N.E. Wyoming. Wyo. State For. Div.

147. McKell, C. M.
n.d. Rehabilitation of disturbed sites and processed oil shale disposal piles. Final rep. of research by Inst. for Land Rehabilitation, Utah State Univ., Logan. [Research sponsored by White River Shale Project, Vernal, Utah.]

148. McMillion, L. G.
n.d. Energy related groundwater monitoring and techniques development. Environ. Protec. Agency, Las Vegas, Nev. [Including monitoring the change in groundwater quality as a result of oil shale mining.]

149. Mead, R. W., and A. V. Kneese.
n.d. Non-ferrous mining industry. Univ. N.Mex., Albuquerque. [Analysis of the environmental problems of the non-ferrous metal mining industry.]

150. Melfi, S. H., and D. N. McNelis.
n.d. Western energy environmental monitoring study. Environ. Protec. Agency, Las Vegas, Nev. [Involves the assessment and the development of monitoring techniques of energy related impacts.]

151. Miller, E. V.
n.d. Control technology for mine reclamation. U.S. Dep. Health and Welfare, Food and Drug Admin., Washington, D.C. [Includes surface manipulations and vegetation trials related to specific problems of reclamation sites.]

152. Miller, J.
n.d. Environmental and health effects. Unpubl. rep., Uranium Information Network. [The paper discusses the environmental and health effects of uranium mining and milling wastes. An extensive bibliography is included.]

153. Monson, S. B., and B. Z. Richardson.
n.d. Tree and shrub planting techniques on mine spoils. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

154. Montana Department of State Lands.
n.d. Bentonite mining related reclamation problems in the northwestern states. Helena, Mont.

155. O'Boyle, P.S.
1978. Report on the investigation of aquifer systems and geologic models for aquifer-recharge in the upper San Miguel drainage basin, Telluride area. 6 p. Unpubl. rep. submitted to Town Board of Telluride, Colo., Jan. 1978. [This report deals with systemic geologic conditions in the Upper San Miguel Drainage Basin and the way geologic structure, stratigraphy, lithology, and geochemistry affect the movement of surface and ground water. The report documents and describes the nature of surface and subsurface water and solute transport and details the results of geochemical, geophysical, hydrological, hydraulic, and geologic investigations within the area of interest.]

156. O'Bryan, C. L.
n.d. Technical literature searches [includes oil shale]. Current research, Bibliography Service, Univ. N.Mex., Albuquerque.

157. Orr, H. K.
n.d. Survival and growth of selected tree and shrub species on bentonite mine spoils near Colony, Wyoming and associated spoil characteristics. S.Dak. Sch. Mines and Technol., Rapid City.

158. Orr, H. K., A. J. Bjugsted, and R. Kerbs.
n.d. Survival and growth of containerized vs. bare root shrub and tree planting stock on bentonite spoils in northeast Wyoming. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Rapid City, S.Dak.

159. Packer, P. E.
n.d. Mine spoil reclamation in the Intermountain and Northern Rocky Mountain regions (WMR). USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

160. Potter, L. D.
n.d. A study of the inhibitive factors of mancos shale for plant growth. Univ. N.Mex., Albuquerque.

161. Potter, L. D.
n.d. A study of radon emission from uranium mill tailings as related to cover and vegetation. Univ. N.Mex., Albuquerque.

162. Richardson, B. Z.
n.d. Physical, chemical and biological properties of spoil materials from phosphate surface mining that inhibit growth. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah. [Current research.]

163. Richardson, B. Z.
n.d. Methods and techniques for the establishment of grass on steep slopes. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

164. Richardson, B. Z.
n.d. Reduction of high sodium content in western coal mine spoils with time. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

165. Richardson, B. Z.
n.d. Use of organic soil amendments in the revegetation of heavy metal surface mined areas. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

166. Richardson, B. Z., and E. E. Farmer.
n.d. The establishment of vegetation on high sodium content mine spoils -Decker, Montana. USDA For. Ser., Intermt. For. and Range Exp. Stn., Logan, Utah. [Current research.]

167. Richardson, B. Z., and E. E. Farmer.
n.d. Evaluation of straw and wood fiber as mulching materials on surface mined areas in the West. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

168. Richardson, B. Z., and E. E. Farmer.
n.d. Physical, chemical and biological properties of spoil materials resulting from toxic, heavy metals mining that inhibit plant growth. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah. [Current research.]

169. Richardson, B. Z., and E. E. Farmer.
n.d. Hydromulching as an alternative mulching method on high sodium surface mine disturbances. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

170. Richardson, B. Z., and E. E. Farmer.
n.d. Physical, chemical and biological properties of spoil materials resulting from Idaho phosphate mining that inhibit plant growth. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

171. Richardson, B. Z., and E. E. Farmer.
n.d. Species adaptability on Idaho phosphate, Montana coal and Idaho heavy metal spoils: assess by greenhouse bioassay techniques. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

172. Richardson, B. Z., and E. E. Farmer.
n.d. Chemical treatments, hydraulic planting and mulching as a revegetation method on steep overburden piles. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

173. Richardson, B. Z., E. E. Farmer, and R. W. Brown.
n.d. Establishment of vegetation on phosphate surface mine spoils at the Ballard Mine, Idaho. USDA For. Serv., Intermt. For. and Range Exp. Stn., Logan, Utah.

174. Russell, K. R.
1978. Overview of a proposal to prepare alternative wildlife replacement plans in response to phosphate resource development, southeastern Idaho. [Unpubl. proposal.]

175. Russo, R. C., R. V. Thurston, and R. K. Skogerboe.
n.d. Toxic effects on the aquatic biota from coal and oil shale development. Mont. State Univ., Bozeman.

176. Sabey, B. R., A. J. Bjugsted, and C. E. Boldt.
n.d. Use of wood chip as a mulch in the reclamation of bentonite mine spoils. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Rapid City, S.Dak.

177. Sanks, R. L.
1977. The use of municipal sludge and municipal solid waste as soil amendments. Final rep. to USDA Forest Service. [The findings were that growth was greatly enhanced and comparable to growth obtained by the use of stripped and reclaimed topsoils.]

178. Scott, R. B.
n.d. Evaluation of 3 permeable limestone seals via construction of 3 eastern dams. Environ. Protec. Agency, Cincinnati, Ohio. [The limestone in the seal will react with the acid water to neutralize acidity and to precipitate ferric and aluminum hydroxides that will tend to plug the voids between stones and prevent water flow.]

179. Shen, H. W.
n.d. Erosion effects and pollutant movements from coal and oil shale strip-mining deposition. Colo. State Univ., Fort Collins.

180. Shetron, S. G.
n.d. Mine waste rehabilitation - non-metallic mines. Mich. Tech. Univ., Houghton. [Revegetation of limestone wastes - future studies will include other non-metal mines.]

181. Simes, P. L.
n.d. Reclamation of mining wastes in south central Colorado. Colo. State Univ., Fort Collins. [Includes colomite and limestone mining wastes.]

182. Skaptason, J. B.
n.d. Determination of natural recurrence of soil decomposer populations on reclaimed mine areas. Western Energy and Land Use Team, Off. Biol. Serv., U.S. Dep. Interior, Fish and Wildlife Serv., Fort Collins, Colo.

183. Smalley, G. H., P. T. Tueller, and E. L. Miller.
n.d. Revegetation of copper mine tailings and overburden in eastern Nevada. Unpubl. ms., Div. Renewable Nat. Resour., Univ. Nevada, Reno. 66 p.

184. Sorensen, D. L., D. B. Procella, and B. Z. Richardson.
n.d. Established microbial population in spoil materials of selected saline characterized surface mines. Utah State Univ., Water Res. Lab., Logan.

185. Southern California Rock Products.
1978. Model: sand and gravel mining operation. (Unpubl. rep.) [This paper documents sand and gravel mining operations in Southern California and the reclamation programs for each operation. In some cases, reclamation is complete--a new park or housing development. In other cases, the reclamation program is in planning stages.]

186. Thorsen, G. W.
1970. Holden tailings. Wash. State Dep. Nat. Resour., Div. Mines. Unpubl. rep. [Mar. 3, 1970].

187. Thurston, R. V.
n.d. Toxic effects on the aquatic biota from coal and oil shale. Florida Inst. Tech., Jensen Beach.

188. Thurston, R. V., R. C. Russo, and R. K. Skogerboe.
n.d. Toxic effects on the aquatic biota from coal and oil shale development. Mont. State Univ., Bozeman, and Colo. State Univ., Fort Collins.

189. Tinlin, R., and L. G. Everett.
n.d. Groundwater research monitoring of energy related developments. General Electric Co., Santa Barbara, Calif. [Development of groundwater monitoring model and strategy.]

190. USDA Agricultural Research Service.
n.d. Revegetation of areas disturbed by man in the central high plains with trees, shrubs, and other woody plants. USDA Agric. Res. Serv., Cheyenne, Wyo.

191. Uresk, D., and T. Yamamoto.
1979. Growth of plants on bentonite spoil under greenhouse conditions. Paper presented at 1979 annu. meet., Soc. Range Manage. [Casper, Wyo., Feb. 12-16, 1979]. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins.

192. Weir, D. N.
1977. Water use and treatment at a placer gold mining site in relation to the local distribution of some anadromous fishes. Unpubl. rep., Tuluksak Dredging Ltd., Nyal, Bethal, Alaska. [This report describes the reduction of process water turbidity in 1976 at a placer gold dredging site on the Tuluksak River, in the Kilbuck Mountains of southwestern Alaska, in compliance with draft Environmental Protection Agency regulations. It also assesses mining activities in relation to the local spawning distribution of king salmon, *Ochorynchus tshawytscha*, and includes notes on some other salmonid fishes. The study was made in close consultation with officers of the Alaska Department of Fish and Game. It was funded by the dredging company and by the Placer Miners Committee of the Alaska Miners Association.

193. Weir, D. N.
1978. Environmental considerations in new placer mine proposals in the Candle Area, Alaska. 16 p. Unpubl. rep. for C. C. Hawley and Associates, Inc. [The report notes some environmental factors and describes features of the ecosystem, including past human impact. Assuming any new mining would be in Candle Creek, the inner Kiwalik Flats, or on Mud Creek, the report also considers for each site water treatment relative to environmental regulations, the revegetation of disturbed ground, and possible wider effects on widllife. Information collected in the reconnaissance period is only summarized here.]

194. Wienke, C. L.
n.d. Ecological investigation of rehabilitation of uranium mine tailings of the south-eastern U.S. Los Alamos Sci. Lab., N.Mex. [Rehabilitation/stabilization alternatives discussed and evaluated.]

195. Willard, B. E., and R. William.
n.d. 20 years of recovery of alpine tundra following protection from visitors, Trail Ridge, Rocky Mtn. Nat'l. Park, Colorado. Colo. Sch. Mines. [Current research.]

196. Wuilstein, L. H.
n.d. Evaluation of plant growth in covered and uncovered radioactive mine tailings (VITRO) in relation to control and radon emissions. Univ. Utah, Salt Lake City.

197. Yamamoto, T., and A. J. Bjugsted.
n.d. Trend-surface analysis of Powder River Basin, Wyoming, Wyoming-Montana, and Williston Basin, North Dakota. S.Dak. Sch. Mine Technol., Rapid City.

198. Yamamoto, T., and D. Uresk.
n.d. Growing shrub and tree species on bentonite spoil under greenhouse (part 1) and field (part 2) conditions. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins.

C. Land Use Planning and Public Policy

Section C contains citations that relate to land-use planning and public policy. Planning in mining and reclamation requires previous land use decisions. Federal and State guidelines for land-use decisions and public policy in reclamation are included.

199. Amir, S.
1975. Surface gravel excavation and environmental quality: a resource management policy. J. Environ. Manage. 3(2):77-89.

200. Bamberg, S. A.
1975. Approaches to large scale land reclamation in oil shale development. In Environmental Oil Shale Symposium Proc. [Oct. 9-10]. p. 95-103. J. H. Gary, ed. Colo. Sch. Mines, Quarterly 70(4). 244 p.

201. Berklund, C.
1974. Managing the public lands for minerals--energy. In Pac. Southwest Energy and Minerals Conf. Proc. [Nov. 11, 1974, Denver, Colo.]. U.S. Dep. Interior, Bur. Land Manage., Denver, Colo.

Some priorities in land management as seen today are discussed. New dealings with land management are examined. The current and proposed programs of the Bureau of Land Management (BLM) are designed to assure adequate supplies of fossil fuels and minerals, and include development of outer continental shelf areas, transportation of Alaska oil and gas, oil shale leasing programs in the western U.S., leasing of Federal coal reserves, and development of a management tool for leasing coal resources on public lands; these programs follow congressional actions on surface mining and air quality regulations. The opportunity for new energy and mineral resources lies in BLM's land-use planning system with no legislation for national policy and guidelines to manage national resource lands properly. Legislation dating back over a hundred years has resulted in some 3,000 laws; these have resulted in conflicts and environmental impacts. The production of nonenergy minerals is failing to meet demand, but BLM is attempting to provide a harmonious relationship between mineral development and protection of other resources on the public domain.

202. Carroll, T. E.
1972. Updating the policies and activities of the Environmental Protection Agency as related to the mining industry. Mining Congr. J. 58(12):61-63.

203. Copeland, O. L., and P. E. Packer.
1972. Land use aspects of the energy crisis and western mining. J. For. 70(11): 671-675.

204. Duesterhaus, R. L.
1970. Gravel pit today, subdivision tomorrow. Soil Conserv. 36(2):32-33.

205. Ellis, S.
1977. Guide to land cover and use classification systems employed by western governmental agencies. Ecology Consultants, Inc., Fort Collins, Colo. 184 p. [Available NTIS as PB-265 173/AS.]

206. Gist, C. S., and others.
1975. A simple method for evaluating alternatives to a proposed environmental alteration: its history, and an example of its use in oil shale development. Colo. Sch. Mines Quarterly 70(4):29-74.

207. Graves, F. M., and others.
1977. Energy, public choices, and environmental data needs. Inst. Public Admin. and Natl. Wildl. Fed. 61 p. [Available NTIS as PB-272-263.]

208. Guernsey, J. L., L. A. Brown, and A. O. Perry.
1978. Integrated mined-area reclamation and land-use planning, vol. 3C. A case study of surface mining and reclamation planning. 122 p. Georgia Kaolin Company Clay Mines, Washington County, Ga. [Available NTIS as ANL/EMR-1 (V.3C).]

The case study examines the reclamation practices of the Georgia Kaolin's American Industrial Clay Company Division, a kaolin producer centered in Twiggs, Washington, and Wilkinson Counties, Georgia. The State of Georgia accounts for more than one-fourth of the world's kaolin production and about three-fourths of the U.S. kaolin output. The mining of kaolin in Georgia illustrates the effects of mining and reclaiming lands disturbed by area surface mining. The disturbed areas are reclaimed under the rules and regulations of the Georgia Surface Mining Act of 1968. The natural conditions influencing the reclamation methodologies and techniques are markedly unique from those of other mining operations. The environmental disturbances and procedures used in reclaiming the kaolin mined lands are reviewed and implications for planners are noted.

209. Hansen, R. P., W. A. Hillhouse II, B. E. Willard, and others.
1970. Public land policy and the environment, vol. 2, part II: Environmental problems on the public lands. Summary statement and case studies 1 through 8. 409 p. Rocky Mountain Center on Environment, Denver, Colo. [Available NTIS as PB-196 169.]

Volume 2 of the study on public land policy and the environment contains eight case studies, each of which discusses land uses or management practices on public lands having environmental consequences and an initial summary chapter which draw together the overall implications of these studies and those contained in vol. 3 (part 2 continued) of the report.

210. Hill, A. D.
1973. Pave old gravel pit: town gets sanitary land fill. Roads and Streets 116(8):104.

211. Imhoff, E. A., T. O. Firz, and J. R. LaFevers.
1976. A guide to State programs for the reclamation of surface mined areas. U.S. Dep. Interior, Geol. Surv. Circ. 731, 33 p.

The status, content, and general trend of State programs for the reclamation of surface mined areas is discussed.

212. LaFevers, J. R. , L. A. Brown, and R. C. Fountain.
1977. Integrated mined-area reclamation and land use planning, vol. 3B. Argonne National Lab., Ill. 71 p. [Available NTIS as EMR-1(V.3B).]

The reports in this series are designed primarily to familiarize professional land use and resource planners with the range of possibilities and effective procedures for achieving integrated mining, reclamation, and land-use planning. These reports are based on a research program which included an extensive literature review, the compilation and analysis of case study data, and close coordination and interaction with related government programs. In volume 3, A Guide to Mined Area Reclamation Technology for Reclamation and Land Use Planners, the methods used to reclaim land in each of several mineral industries are discussed in relation to the physical and cultural constraints that must be considered in planning a reclamation program. Much of the information for this document was obtained from case studies conducted in several mining districts. Volume 3B presents data from a case study of surface mining and reclamation planning, International Minerals and Chemical Corporation, Phosphate Operations, Polk County, Fla.

213. Landerman, N. J., S. Schwartz, and D. R. Tapp.
1972. Community resource: the development-rehabilitation of sand and gravel lands. Calif. State Polytech. Univ., Pomona, Sch. Environ. Design, Dep. Landscape Architecture 63 p.

214. Lewis, L. R., A. O. Perry, and J. R. LaFevers.
1977. Integrated mined-area reclamation and land use planning, vol. 3A. Argonne National Lab., Ill. 96 p. [Available NTIS as ANL/EMR-1(V.3A).]

This case study details reclamation planning for the Flatiron Companies' South Boulder Creek Park Project in Boulder, Colo. The site contains a deposit of high-quality sand and gravel considered to be one of the best and largest known deposits of aggregate materials in the Front Range area. The aggregate deposit is located in a highly visible site just off the Denver-Boulder Turnpike at the entrance to the city from Denver, and adjacent to a residential portion of the city. In order to make maximum use of premining planning, as a tool for resolving a conflict over the company's proposed operation, an extensive cooperative planning effort was initiated. This included the preparation of an environmental impact assessment, numerous public hearings, operating and reclamation plan review by city authorities, annexation of the site to the city, and the granting of a scenic easement on the property to the city for the development of a regional recreation park. A suite of contractual agreements was worked out among Flatiron Companies, the City of Boulder, the Colorado Open Lands Foundation, and the Federal Bureau of Outdoor Recreation. The purpose of this case study is to allow the planner to gain insight into the procedures, possibilities, and constraints involved in premining planning in a cooperative situation.

215. Matter, F. S., and others.
1974. A balanced approach to resource extraction and creative land development associated with open-pit copper mining in southern Arizona. 85 p. Univ. Ariz., Tucson, Coll. Architecture, Coll. Mines.

216. Moore, R., and T. Mills.
1977. Federal leasable and locatable mineral regulations: an environmental guide for resource managers. 84 p. Ecology Consultants, Inc., Fort Collins, Colo. [Available NTIS as PB-272 153/8GA.]

This report contains a compilation of Federal environmental regulations pertaining to surface mining operations in three geomorphic regions of the western United States: Northern Great Plains Region, Rocky Mountain Region, and Intermountain and Arid Southwest Regions. Specific minerals covered are: coal, oil shale, phosphate, bentonite, copper, gypsum, and uranium. Aspects of surface mining are presented in horizontal flow diagrams with application points of the aforementioned regulations illustrated. Particular emphasis is given to points of application where agency input regarding protection of fish and wildlife values is possible.

217. Oxford, T. P., and L. G. Bromwell.
1977. Planning for phosphate land reclamation, Central Florida. Proc., Conf. on Geotech. Pract. for Disposal of Solid Waste Matter [Univ. Mich., Ann Arbor]. p. 715-726. Am. Soc. Civil Eng., New York.

This paper describes considerations involved in the development of a life-of-mine plan for the disposal of wastes and the restoration of land to beneficial use for a future mining tract in central Florida. The arrangement and cost of waste clay settling areas, minimization of disturbance to unminable areas, the interface between the operation and the surrounding community, the presence of wetland areas, and the selection of reclamation techniques are among the concerns that are addressed.

218. Paone, J., J. L. Morning, and L. Giorgetti.
1974. Land utilization and reclamation in the mining industry, 1930-71. U.S. Bur. Mines, Rep. No. Bumines-1C-8642, 68 p. Washington, D.C. [Available NTIS as PB-233 955/4.]

Land utilized by the mining industry from 1930 through 1971 amounted to 3.65 million acres, or 0.16 percent of the land mass in the United States. Land reclaimed during the same period was 1.46 million acres, or 40 percent of the land utilized. This report includes data on land use for wastes from underground and surface mining, for wastes from mill operations, and on subsidence. Data on land use and reclamation were obtained from operating companies, mining organizations, appropriate State agencies, and others concerned with such activities.

219. Parker, H. D.
1974. Remote sensing for western coal and oil shale development planning and environmental analysis. In Remote Sensing Applied to Energy Related Problems, Symposium [Miami, Fla., Dec. 2-4] Proceedings. p. S4:3-S4:25. T. N. Veziroglu, ed. Univ. Miami, Coral Gables, Fla.

220. Pickels, G.
1970. Realizing the recreation potential of sand and gravel sites. Research project of the Univ. of Illinois. 75 p. Natl. Sand and Gravel Assoc., Silver Springs, Md.

221. Rogers, W. L.
1975. The oil shale environmental advisory panel, the environment, and the Federal program: past, present and future. Colo. Sch. Mines, Quarterly 70(4):1-18.

222. Robertson, J. L.
1975. Dredging and reclamation plans govern Kenosha materials sand and gravel operations. Rock Products 78(4):42-45.

223. Rounsaville, H. D.
1977. Guidelines for estimating potential land capability and range sites as a part of reclamation planning and alternative analysis - Thunder Basin National Grasslands. 47 p. USDA For. Serv., Medicine Bow Natl. For., Laramie, Wyo.

Here is a guide for the estimation of potential reclaimed land capability and range sites for drastically disturbed lands. The guide is an adaptation of the procedures developed by the USDA Soil Conservation Service for land capability and range sites classification of natural soils and landscapes. The validity of the approach is dependent upon data accuracy and the output is in terms of predicted potentials.

224. Schellie, K. L., and A. M. Bauer.
1968. Shaping the land-planned use of industrial sand deposits. 46 p. Natl. Sand and Gravel Assoc., Silver Springs, Md.

225. Schellie, K. L., ed.
1977. Sand and gravel operations - a transitional land use. 212 p. Natl. Sand and Gravel Assoc., Silver Springs, Md.

This paper provides a valuable handbook on transitional land use. It includes chapters on environmental impact statements, preplanning, land use potentials, and site improvement practices. It gives practical guidelines, excerpts from reclamation rules and regulations as well as two research case studies (a wet and a dry site). Examples of industry programs are also given.

226. Swan, D.
1973. Relationship of the environment and public policy. Mining Congr. J. 59(2):74-76.

227. Teska, R. B.
1973. Where there's room for everything: a 234,500 acre plan in an old copper-mining region. Landscape Architecture 63(3):256-265.

228. Thames, J. L., T. R. Verma, and J. R. LaFevers.
1977. Integrated mined-area reclamation and land-use planning, vol. 3E: a case study of surface mining and reclamation planning; Asarco Open Pit Copper Mine, Casa Grande, AZ. Argonne National Laboratory, Ill. [Available NTIS as 78:006132.]

The reports in this series are designed primarily to familiarize professional land use and resource planners with the range of possibilities and effective procedures for achieving integrated mining, reclamation, and land-use planning. These reports are based on a research program which included an extensive literature review, the compilation and analysis of case

study data, and close coordination and interaction with related government programs. This volume presents a case study of surface mining and reclamation planning at the ASARCO open pit copper mine, Casa Grande, Ariz.

229. Thieme, W. I.
1968. Gravel land zoning and rehabilitation. 7 p. Presented at Mich. Highway Conference [March 1968, Grand Rapids, Mich.].

Reclamation, in sand and gravel mining, is good business. Suggestions are given to help mitigate objectionable effects of the mining. Alternate land use ideas for eventual reclamation are also given.

230. Tully, W. P., and C. N. Lee.
1975. Hydrologic and environmental impact budgeting for a quarry tailings pond. In Watershed management. p. 80-95. Am. Soc. Civil Eng., New York.

231. Turcott, G.
1975. Minerals management on the public lands. In Rocky Mountain Energy-Minerals Conference Proc. [Billings, Mont., Oct. 15-16]. p. 8-19. U.S. Bur. Land Manage., Billings. 294 p.

232. U.S. Department of the Interior, Bureau of Outdoor Recreation.
1976. Preplanning: surface mining for outdoor recreation. 22 p. [Available GPO as I 66.2 SU7/2 or stock number 2416-00068.]

233. Williams, C. E., and Associates, Inc.
1972. The use of sand and gravel pits for sanitary landfills. 139 p. Natl. Sand and Gravel Assoc., Silver Springs, Md.

234. Wobber, F. J., and K. Martin.
1977. Aerial photographic and satellite image application. World Min. 3(4):53-57.

Based on tests conducted in Florida, large scale color and color infrared aerial photography are well suited for all types of phosphate mining analysis including mine design, and reclamation planning, inventory, impact assessments, and reclamation monitoring. Small scale aerial photography can be used for inventorying phosphate mined lands and associated land use features, such as tailing ponds. Repetitive satellite imagery provides an economical means of acquiring general reclamation data on a periodic basis. Satellite imagery has been successfully used to detect major phosphate mining and processing operations during preliminary analyses conducted in the Florida phosphate mining district.

D. Economic and Legal Aspects

Section D presents reclamation and pollution control as components of a more complicated whole. Citations dealing with the economic impact of reclamation and pollution control are included. Also included are citations on legal aspects which show existing and sometimes conflicting Federal, State, and local regulations.

235. Almond, M. A.
1975. Legal aspects of phosphate mining in North Carolina. 31 p. North Carolina Univ., Chapel Hill, Sch. Law. [Available NTIS as COM-75-10504/9ST.]

The article presents the ecological dilemma in a complex setting. The removal of phosphate from beneath navigable waters of North Carolina may produce adverse effects upon marine life adjacent to the operation. On the other hand, the phosphate is critically needed to provide fertilizer to increase crop yields in a hungry world. The ecological resolution of this scientific, economic, legal, political, and humanistic problem is not simple. The author sets forth the pertinent North Carolina statutes and legal thinking likely to be used in the administrative or legal solution of this problem. He points out that wide discretion is vested in State officials and that where several worthwhile interests are to be reconciled and where delicate policy decisions must be made, flexible regulation may well provide the only viable answers.

236. Arthur D. Little, Inc.
1978. Economic impact of environmental regulations on the United States copper industry. 516 p. Arthur D. Little, Inc., Cambridge, Mass. [Available NTIS as PB-278 280/3GA.]

This report estimates, by use of an econometric model, the economic impact of environmental regulations on the United States copper industry. The report covers the principal air and water regulation as they affect copper mining, milling, smelting, and refining. Price, employment, production, and net imports are forecast over the period 1978-1987 both with and without present environmental regulations.

237. Banks, C. E., R. I. Benner, L. L. Brannick, and others.
1975. Technical and economic study of an integrated single pass mining system for pit mining of deep oil shale deposits. 260 p. Sun Oil Co., Richardson, Tex. [Available NTIS as PB-250 525/3ST.]

Data were collected on the geology and hydrology of the Green River formation in the Piceance Creek Basin, Colorado, on mining reclamation methods and cost, and on surface mining and crushing methods and costs. Data were organized into tables, graphs, and flow charts for engineering analysis. Data from eight large surface mines and a preliminary mine layout for a pit producing 1.25 million tons per day are included in the report.

238. Carter, L. J.
1978. Uranium mill tailings: Congress addresses a long-neglected problem. Science 202:191-195.

239. Cook, C. F.
1978. Memorandum: (Environmental Aspects Subcommittee/COSMAR) Comments relating to provisional list of environmental problems connected with mining. [Unpubl. rep. to COSMAR and to Southern California Rock Products.]

The memorandum accounts for the many existing Federal statutes, State statutes, Federal regulations, and programs now in existence or being implemented to deal with each environmental aspect mentioned in "Provisional List of Environmental Problems Connected with Mining," by Environmental Subcommittee, COSMAR.

240. Davis, J. F.
1978. Carrying out the policy rules and regulations of the California Surface Mining and Reclamation Act (SMARA). Testimony presented to COSMAR panel on construction materials, Nov. 2, 1978, Pasadena, Calif.

This paper is concerned with the reclamation of mined land in California under California's Surface Mining and Reclamation Act of 1975 (SMARA). It covers the intent and mechanism of the Act itself, the performance of the several organizations responsible for carrying it out, and the results achieved so far in its history. The paper also compares the mechanisms of SMARA with those of the Federal Surface Mining Control and Reclamation Act of 1977, PL95-87 (SMCARA). Finally, it discusses possible modifications of SMCARA to make it effective and reasonable, if it is to be applied to surface mining in California for minerals other than coal.

241. Mining Congress Journal.
1977. AMC and NCA testify on surface mining legislation. Mining Congr. J. 63(2):100-107.

242. Spence, H. M.
1975. Cost factors in environmental protection and planning. In Environmental Oil Shale Symposium Proc. [Oct. 9-10]. p. 75-87. J. H. Gary, ed. Colo. Sch. Mines, Quarterly 70(4). 244 p.

E. Effects on Air Quality

Section E includes citations on air pollution, monitoring, and control. Citations dealing with effects of air contaminants on health are included in section J and are cross-referenced in the index under "Air Effects."

243. Breslin, A. J., A. C. George, and M. A. Weinstein.
1969. Investigation of the radiological characteristics of uranium mine atmospheres. 43 p. New York Operations Office (AEC), New York Health and Safety Lab. [Available NTIS as HASL-220.]

244. Davis, W. E., and Associates.
1973. Emission study of industrial sources of lead and air pollutants. 133 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as RC A07/MF-A01.]

This report has been prepared to provide reliable information regarding the nature, magnitude, and extent of lead emissions from industrial sources in the United States for the year 1970. Background information concerning the basic characteristics of the lead industry has been assembled and included. Brief process descriptions, limited to areas closely related to existing or potential atmospheric losses of lead, are included. Lead emissions and emission factors are presented.

245. Davis, W. E., and Associates.
1972. National inventory of sources and emissions, barium, section I. 56 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-210-686.]

Information is provided regarding the nature, magnitude, and extent of the emissions of barium in the United States for the year 1969. Background information concerning the basic characteristics of the barium (barite) industry has been assembled and included. Brief process descriptions are given; they are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant. Emissions to the atmosphere during the year were 15,420 tons. Nearly 18 percent of the emissions resulted from the processing of barite, more than 28 percent from the production of chemicals, 23 percent from the manufacture of various end products, and about 26 percent from the combustion of coal. The wear of rubber tires was a relatively minor emission source.

246. Davis, W. E., and Associates.
1972. National inventory of sources and emissions, boron, section II. 51 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-210 677.]

Information is provided regarding the nature, magnitude, and extent of the emissions of boron. Background information concerning the basic characteristics of the boron industry has been assembled and included. Process descriptions are given, but they are brief, and are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant. Emissions to the atmosphere during the year were 11,003 tons. Nearly 22 percent of the emissions resulted from the processing of boron compounds, more than 34 percent from the manufacture and use of various end products, and about 43 percent from the combustion of coal. Emission estimates for processing and the manufacture of end use products are based on unpublished data obtained from industrial sources.

247. Davis, W. E., and Associates.
1972. National inventory of sources and emissions, copper, section III. 74 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-210 678.]

Information is provided regarding the nature, magnitude, and the extent of the emissions of copper in the United States for the year 1969. Background information concerning the basic characteristics of the copper industry has been assembled and included. Brief process descriptions are given; they are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant. Emissions to the atmosphere during the year were 13,680 tons. About 64 percent of the emissions resulted from the metallurgical processing of primary

copper, and about 20 percent from the production of iron and steel. The combustion of coal was the only other significant emission source.

248. Davis, W. E., and Associates.
1972. National inventory of sources and emissions, selenium, section IV. 57 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-210 679.]

Information is provided regarding the nature, magnitude, and extent of the emissions of selenium in the United States for the year 1969. Background information concerning the basic characteristics of the selenium industry has been assembled and included. Brief descriptions are given; they are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant. Emissions to the atmosphere during the year were 986 tons. The emissions that resulted from the combustion of coal were about 65 percent of total emissions, and those due to the manufacture of glass were nearly 21 percent. Emissions from metallurgical processing of nonferrous metals and the burning of fuel oil were 9 and 7 percent respectively, while all other emissions were less than 1 percent of the total.

249. Davis, W. E., and Associates.
1972. National inventory of sources and emissions, zinc, section V. 85 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-210-680.]

Information is provided regarding the nature, magnitude, and extent of the emissions of zinc in the United States for the year 1969. Background information concerning the basic characteristics of the zinc industry has been assembled and included. Brief process descriptions are given; they are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant. Emissions to the atmosphere during the year were 159,922 tons. About 31 percent of the emissions resulted from the metallurgical processing of zinc, more than 30 percent from the production of iron and steel, and nearly 18 percent from the incineration of refuse. The production of zinc oxide, the wear of rubber tires, and the combustion of coal were also significant emission sources.

250. Davis, W. E., and Associates.
1970. National inventory of sources and emissions, cadmium, section I. 53 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-192 250.]

The aim is to provide reliable information regarding the nature, magnitude, and extent of the emissions of cadmium in the United States for the year 1968. Background information concerning the basic characteristics of the cadmium industry has been assembled and included. Process descriptions are given, but they are brief, and are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant. The apparent consumption was 13.3 million pounds, and domestic production 10.6 million pounds. Only a small amount of cadmium was recovered from scrap. Emissions to the atmosphere during the year totaled 4.6 million pounds. Emissions from the metallurgical processing plants of the primary producers of cadmium, zinc, lead, and copper were more than 2 million pounds, and those from melting operations in the iron and steel industry were about the same. Emission estimates for mining, metallurgical processing, and reprocessing operations are considered to be reasonably accurate. They are based on data obtained by personal contact with the processing and reprocessing companies.

251. Davis, W. E., and Associates.
1970. National inventory of sources and emissions, nickel, section II. 46 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-192 251.]

The aim is to provide reliable information regarding the nature, magnitude, and extent of the emissions of nickel in the United States for the year 1968. Background information concerning the basic characteristics of the nickel industry has been assembled and included. Process descriptions are given, but they are brief, and are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant. Consumption for the year was reported to be 159,306 tons and domestic production to be 29,215 tons including the production from both primary and secondary sources. Imports, mostly from Canada, totaled

147,950 short tons. Emissions to the atmosphere during the year were 6,475 short tons. About 83 percent of the emissions were due to the burning of heavy fuel oil and coal. Estimates of emissions for mining, metallurgical processing, and reprocessing operations are based on data obtained by personal contact with processing and reprocessing companies, and are considered to be reasonably accurate.

252. Davis, W. E., and Associates.
1970. National inventory of sources and emissions, asbestos, section III. 56 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-192 252.]

The aim is to provide reliable information regarding the nature, magnitude, and extent of the emissions of asbestos in the United States for the year 1968. Background information concerning the basic characteristics of the asbestos industry has been assembled and included. Process descriptions are given, but they are brief, and are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant. The apparent consumption for the year was 817,363 tons and the domestic production was only 120,690 tons. Imports, mostly from Canada, totaled 737,909 short tons. There was no recovery from scrap. Emissions to the atmosphere during the year were 6,579 tons. About 85 percent of the emissions were due to mining and milling operations. Estimates of emissions are based for the greatest part on observations made during field trips, and on the limited information provided by mining, milling, and reprocessing companies. Information was not available regarding the magnitude of the emissions on the locations visited.

253. Davis, W. E., and Associates.
1971. National inventory of sources and emissions, vanadium-1968. 62 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-221 655/4.]

An emission inventory has been prepared to determine the nature, magnitude, and extent of the emissions of vanadium in the United States for the year 1968. The production and use of vanadium in the U.S. has been traced and charted. The consumption was 5,495 tons, exports 741 tons, and imports 652 tons. About 80 percent was used in the production of steel. Emissions to the atmosphere during the year totaled 19,321 tons. Emissions due to the combustion of fuel oil and coal were 17,000 tons and 1,750 tons, respectively. Emissions resulting from the production of ferrovanadium were 144 tons and those from the production of steel were 236 tons.

254. Douglas, G. W., and A. C. Skorepa.
1976. Monitoring air quality with lichen: a feasibility study. Douglas Ecological Consultants Ltd., Environ. Res. Mongr. 1976-2, 69 p.

A study was undertaken in 1975 to determine the scientific, technical, and economic feasibility of establishing air pollution effect gradients using lichenological methods on a radially arranged pattern of observation sites. The data acquired from 12 lichen sample plots indicate that the flora are sufficiently rich and widespread to allow establishment of a lichen air quality monitoring system. A grid network, containing 56 permanent plots, will provide adequate coverage of the region. Partial resurveys should be conducted annually, at least during the first years of the Syncrude plant's operation. Complete resurveys will only be required if a partial resurvey indicates adverse changes are occurring.

255. Engineering and Mining Journal.
1976. The asbestos industry: facing up to strict emissions limitations. Eng. and Mining J. 177(10):37.

256. Environmental Protection Agency.
1973. Control techniques for asbestos air pollutants. 104 p. Environ. Protect. Agency, Research Triangle Park, N.C. [Available NTIS as PB 222 020/0.]

The report contains information about the nature and control of a hazardous air pollutant--asbestos. The primary purpose of this document is to provide information useful to those involved in the control of emissions of asbestos from industrial sources. The language and

approach are largely technical, but the first two sections should be of interest and value to the general reader. The contents include the following: asbestos emission sources; control techniques and control cost (mining, milling, manufacture, and uses of products, disposal of asbestos waste); costs of control by gas cleaning devices; evaluation of asbestos emissions; and development of new technology.

257. GCA Corporation.
1973. National emissions inventory of sources and emissions: molybdenum. 36 p. GCA Technology Div., Bedford, Mass. [Available NTIS as PB-230 035/8.]

A national inventory of the sources and emissions of the element molybdenum was conducted. The study indicated the preparation of an overall material flow chart depicting the quantities of molybdenum moving from sources of mining and importation through all processing and reprocessing steps to ultimate use and final disposition. All major sources of molybdenum-containing emissions were identified and their molybdenum emissions into the atmosphere estimated. A regional breakdown of these sources and their emissions was also provided. The physical and chemical nature of the molybdenum-containing emissions was delineated to the extent that information was available, and a methodology was recommended for updating the results of the study every 2 years.

258. GCA Corporation.
1973. National emissions inventory of sources and emissions of silver. 43 p. GCA Technology Div., Bedford, Mass. [Available NTIS as PB-231 368/2.]

A national inventory of the sources and emissions of the element silver was conducted. The study included the preparation of an overall material flow chart depicting the quantities of silver moving from sources of mining and importation through all processing and reprocessing steps to ultimate use and final disposition. All major sources of silver-containing emissions were identified and their silver emissions into the atmosphere estimated. A regional breakdown of these sources and their emissions was also provided. The physical and chemical nature of the silver-containing emissions was delineated to the extent that information was available, and a methodology was recommended for updating the results of the study every 2 years.

259. King, J., ed.
1977. Symposium on fugitive emissions: measurement and control [Houston, Tex.]. 544 p. Research Corp. of New England, Wethersfield, Conn., and Industrial Environmental Research Lab., Research Triangle Park, N.C. [Available NTIS as PB-276 973/5ST.]

The proceedings are a compilation of technical papers prepared for presentation at the Second Symposium on Fugitive Emissions, May 23-25, 1977, Houston, Tex. The papers discuss the scope and impact of fugitive emissions (nonpoint sources) and present techniques which have been used to measure these emissions. Fugitive emissions control technologies are also discussed.

260. LeBlanc, F., G. Robitaille, and D. N. Rao.
1976. Ecophysiological responses of lichen transplants to air pollution in Canada. J. Hattori Bot. Lab. 40:27,40,268.

261. MSA Research Corp.
1974. Control of respirable dust in noncoal mines and ore processing mills. 104 p. Bureau of Mines, Washington, D.C. [Available NTIS as PB-240 646/OST.]

The objective of this manual is to provide guidance to the mining community for control of respirable dust based on currently available equipment and techniques. The survey of dust control procedures included ores and minerals and different types of underground and open pit mining operations. Control procedures for dust in processing plants were surveyed. The types of minerals and ores included in the survey were asbestos, bentonite, copper, gold, granite, iron, lead, limestone, molybdenum, phosphate rock, potash, sand and gravel, talc, trona, and uranium. More than 300 Bureau of Mines dust inspection reports were reviewed to establish which work areas are most frequently cited as being above allowable dust concentration. The multiplicity of types of ore and mining and processing practices dictates that mine management

carefully select optimum dust control measures. This requires a determination of the free silica content of the ore since this factor sets the allowable respirable dust concentration and therefore the required efficiency of the dust control techniques.

262. National Research Council.
1971. Airborne asbestos. 61 p. Comm. on Biologic Effects of Atmospheric Pollutants, Washington, D.C. [Available NTIS as PB-198 581.]

The report (1) summarizes the major evidence of the pathogenicity of asbestos in man and animals, (2) summarizes the evidence of human nonoccupational exposure to asbestos, (3) evaluates the evidence of a health risk associated with various degrees and types of exposure, (4) identifies sources of environmental contamination by asbestos, and (5) offers recommendations concerning the need for and feasibility of control measures.

263. Nelson, R.
1975. Meteorological dispersion potential in the Piceance Creek Basin. In Environmental Oil Shale Symp. Proc. p. 223-237. Colo. Sch. Mines Quar. 70(4).

Turbulence in the valleys below the Piceance plateau is predominantly thermal. Therefore, inversion formation and dissipation within the valleys follow extremely predictable diurnal patterns. The depth of these inversions varies widely but seldom reaches more than 300 meters above the surface of the plateau regions and often is wholly contained within the valleys themselves. This formation and dissipation of inversions may lead to serious pollution problems if large pollutant releases are made within the valleys. In this case, fumigation may occur. Location of all plume release points upon the plateau regions will greatly minimize the fumigation effects, if not alleviate it completely. Due to the enhanced mechanical turbulence a short distance above the surface of the plateau regions, plumes released from stacks 300 to 400 feet tall with a plume rise of about another 300 to 400 feet should very seldom produce a severe fumigation effect.

264. Peterson, W. L., and G. W. Douglas.
1977. Air quality monitoring with a lichen network: baseline data. Douglas Ecological Consultants, Environ. Res. Mongr. 5, 79 p.

A network of 56 permanent plots, radiating from the periphery of the Syncrude lease, was established during the summer of 1976. This network will allow continuous quantitative monitoring of the lichen flora using photographic techniques. Since lichens are highly sensitive to air pollutants such as SO_2, they are capable of showing damage or reduced growth long before it is detectable in other vegetation. This "early warning system" may indicate that unnatural biological changes are beginning to take place in the ecosystem and appropriate action, if necessary, may then be taken to minimize further biological changes. It is recommended that partial resurveys of the grid network should be conducted annually during the first years of the Syncrude plant's operation.

265. Rodgers, S. J.
1974. Survey of past and present methods used to control respirable dust in noncoal mines and ore processing mills. 134 p. MSA Research Corp., Evans City, Penn. [Available NTIS as PB-240 662/7ST.]

A survey of methods used to control respirable dust in noncoal mines and ore processing mills was conducted. The survey covered information reported in mining journals, and U.S. Bureau of Mines circulars, dust inspection reports, on-site evaluation of dust control methods and systems, and contact with manufacturers of dust control equipment. Both surface and underground mining operations were visited. Fifty mines and 51 processing plants were included in the survey. Dust control methods for 15 types of ores or mines were studied. The survey showed that the major reasons for overexposure to respirable dust were poor maintenance and housekeeping. Poor maintenance practices were observed in the form of holes in ductwork, missing pieces of ductwork, worn shrouds, plugged spray nozzles, etc. Poor housekeeping practices were observed as piles of dust collected at transfer points and on rafters and beams. Other factors that result in overexposure included muck piles not being wetted down, poor design of dumps and

chutes, dry drilling and undercutting, undersized ventilation equipment, and flow imbalances in exhaust systems.

266. Schultz, L., W. Bank, and G. Weems.
1973. Airborne asbestos fiber concentrations in asbestos mines and mills in the United States. Bureau of Mines, Washington, D.C. Rep. No. TPR-72, 19 p. [Available NTIS as PB-222 611/6.]

Personnel of the Bureau of Mines have conducted investigations in the principal asbestos mines and mills in the United States to determine the concentration of airborne asbestos fibers in the work place, and to establish the exposure of workers to such fibers. The surveys were conducted using the sampling and evaluation method recommended by the National Institute for Occupational Safety and Health. The method consists of collecting the airborne sample on filters and, after appropriate sample preparation, counting the fibers utilizing phase contrast microscopy. The results of the investigation show that fiber concentrations are low in the asbestos mines but high in the asbestos mills, ranging well above 5 fibers/ml of air based on a count of fibers greater than 5 micrometers in length.

267. Shannon, L. J., P. G. Gorman, and M. Retchel.
1971. Particulate pollutant system study. 343 p. Midwest Research Inst., Kansas City, Mo. [Available NTIS as PB-203-521.]

A program was conducted to quantify fine-particle emissions (0.01-2 microns) from particulate pollution sources. The primary objective was to use the best data currently available (1969-1970) on particle-size distributions of particulates from uncontrolled and controlled sources, fractional efficiency curves for specific control devices, and the degree of application of control equipment on specific sources to estimate the mass and number of fine particles emitted from particulate pollution sources. Secondary objectives were the assessment of (1) the applicability of standard sampling and particle sizing methods to the fine particle regime, and (2) the current understanding of the adverse effects of fine particulate pollutants. This report presents the results of this study.

268. Spangler, C. V.
1971. National inventory of sources and emissions: manganese - 1968. 70 p. W. E. Davis and Associates, Leawood, Kans. [Available NTIS as PB-220 620/9.]

The inventory of atmospheric emissions has been prepared to provide reliable information regarding the nature, magnitude, and extent of the emissions of manganese in the United States for the year 1968. Background information concerning the basic characteristics of the manganese industry has been assembled and included. Process descriptions are given, but they are brief, and are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant.

269. Stewart, I. M., R. E. Purscher, H. J. Humecki, and others.
1977. Asbestos fibers in discharges from selected mining and milling activities, part III. 50 p. McCrone Associates, Inc., Chicago, Ill. [Available NTIS as PB-264 288/2ST.]

The Office of Toxic Substances of the EPA has sponsored a nationwide survey to determine the impact of point and nonpoint sources on levels of waterborne asbestos. Part 1 of the final report presented the results of analyses of water from the ten regional cities. Part 2 of the final report presented the results of the analyses of water from natural sources and from point sources manufacturing asbestos products. Part 3 of the final report, contained herein, presents the results of the analyses of water from point sources associated with the mining and milling of potentially asbestos bearing rocks. The results of these analyses indicate that a variety of mineral ore types may have asbestos minerals associated with them and that these fibers are liberated into their effluents. In some instances, however, the final effluent has little impact on levels in the local surface water already have high asbostos contents.

270. Stosher, M. M.
1978. Ambient air quality in the AOSERP study area 1977. Alberta Soil and Environ. Res. Prog. Proj. ME 2.1, 74 p.

The monitoring network for ambient air quality in the AOSERP study area is described with particular reference to site location, instrumentation, measurement techniques, and data sources. The results of 1 to 3 years of data from 68 exposure cylinders and eight continuous monitoring stations are shown in tables and maps. Emission characteristics of the existing and proposed oil sands plants are described and related to processes for bitumen extraction and upgrading. Initial evaluation of data indicates that sulfur dioxide concentrations at ground level in background air are in the 0.001 ppm range. Annual average SO_2 concentrations at monitoring sites closer to the source range from 0.003 to 0.006 ppm. Monthly average levels of O_3 and NO_2 at a background station are approximately 0.045 ppm and 0.01 ppm respectively. Results of total sulfation measurements show no change in levels of total sulfur over the past 3 years. Initial results of total suspended particulates indicate very low levels except at Fort McMurray where levels greater than 100 $\mu g/m^3$ were recorded. The report recommends that a similiar document be prepared which would include all available data prior to the startup of the second oil sands plant.

271. Sullivan, R. J.
1969. Air pollution aspects of nickel and its compounds. 76 p. Environmental Systems Div., Litton Systems, Inc., Bethesda, Md. [Available NTIS as PT-188-070.]

Contains information on nickel's and nickel compound's effects on humans (dermatitis, respiratory disorders, cancer of the respiratory tract); effects on animals; effects on plants; effects on materials; environmental air standards; natural occurrence; production sources (mines, metallurgical industry); product sources; other sources (asbestos, coal, fuel oil, incineration); environmental air concentration; abatement; economics; methods of analysis (sampling methods, quantitative methods [nickel particulates, nickel carbonyl]).

272. Vancura, P. D., and R. E. Chufo.
1978. Air monitor system at Grace Iron Mine - zeroing in on hazardous working areas. Eng. and Mining J. 179(4):92-94.

273. Vandegrift, A. E., L. J. Shannon, P. G. Gorman, and others.
1971. Particulate pollution systems study, vol. I. Mass emissions. 376 p. Midwest Research Inst., Kansas City, Mo. [Available NTIS as PB-203 128.]

A program on particulate air pollution from stationary sources in the continental United States was conducted. The specific objective of the study was to identify, characterize, and, to the extent possible, quantify the particulate air pollution problem. Information was to be assembled and analyzed on the kind and magnitude of specific sources, and the status of current control practices. The resultant information was to be used to identify deficiencies in current knowledge regarding the nature of important particulate pollution sources, and to provide requisite handbook data for the design and application of control devices. The results of the study are presented.

274. Vandegrift, A. E., L. J. Shannon, E. W. Lawless, and others.
1971. Particulate pollutant systems study, vol. III. Handbook of emission properties. 613 p. Midwest Research Inst., Kansas City, Mo. [Available NTIS as PB-203 522.]

A handbook is presented as part of the documentation for a study of particulate air pollution from stationary sources. The objective of the study was to identify, characterize, and quantify the particulate air pollution problem in the United States. The document delineates the kind and number of stationary particulate sources, the chemical and physical characteristics of both the particulates and carrier gas emitted by specific sources, and the status of current control practices. The first three chapters of the handbook present general background information pertaining to source emission factors and emission rates, effluent characteristics, and control technology. The next chapter discusses some of the more important chemical and physical properties of particulates and carrier gas emitted by industrial sources. The remaining chapters present discussions of the major industrial sources of particulate pollutants.

275. Walmsley, J. L., and D. L. Bagg.
1977. Calculations of annual averaged sulphur dioxide concentrations at ground level. Alberta Oil Sand Environ. Res. Prog. Proj. ME 4.1, 40 p.

The Climatological Dispersion Model and the input data required for calculation of annual averaged values of sulfur dioxide concentrations at ground level are described. The most important meteorological input to the model is the long-term joint frequency distribution of winds in the vicinity of the sources of atmospheric pollution. These data are computed with the help of statistics of wind correlations between Fort McMurray and Mildred Lake, Alberta. Numerical experiments are performed with and without parameterized pollutant removal processes. The effect of incorporating terrain in the model is examined. Experiments comparing concentrations due to existing sources with those due to existing and future sources are performed. Results are also compared with observational data from pollution monitors and snowpack sampling. Estimates are made of sulfur loading due to dry deposition.

F. Effects on Water

Citations in section F are subdivided into three categories: (1) water quality, (2) acid mine drainage, and (3) effects on ecology and biota. Citations included under water quality are those citations which deal with general water pollution, control, and with impacts of surface mining on hydrology and consumptive water use. Subsection 2 separates acid mine drainage as a special problem. Numerous citations exist describing the acid mine drainage problem. However, most of these describe the problem as it exists in coal mining in the East (see bibliographies 4, 10, 49, and 60). Acid mine drainage is also a major problem associated with heavy metals and some coal mining in the West (see citations 352, 359, and 364). Citations included in this section deal with solutions to the problem of acid mine drainage, which can be applied in both eastern and western mining. Citations in subsection 3 include those which deal primarily with the effects of mine water pollution on the ecology and biology of aquatic ecosystems. (See also "fish" under "fauna" in the index.)

1. WATER QUALITY AND HYDROLOGICAL ASPECTS

276. Battelle Memorial Institute.
1975. Water pollution abatement technology capabilities, ore mining and milling. 2603 p. Battelle Memorial Inst., Richland, Wash. [Available NTIS as PB-251 437/OST.]

Technologies are examined for 38 industry segments to meet water pollution abatement requirements of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500). Levels of pollution abatement which are reviewed include those promulgated by the U.S. Environmental Protection Agency for 1977 (PBCTCA or best practicable control technology currently available) and for 1983 (BATEA or best available technology economically achievable). Capital and operating and maintenance costs are presented in 1973 dollars. Performance is stated in terms of resulting effluents.

277. Battelle Memorial Institute.
1971. Inorganic fertilizer and phosphate mining--water pollution and control. 228 p. Battelle Memorial Inst., Richland, Wash. [Available NTIS as PB-206 154/7ST.]

A state-of-the-art survey was made of the water pollution problems that result from the production of inorganic fertilizers and phosphate rock. Information required to complete the study was obtained through an extensive literature search, questionnaires sent to the major fertilizer producers, and visits to selected production plants. Ninety-eight plants representing 33 different companies were surveyed. Production figures since 1940 and estimates of production through 1980 were accumulated for phosphate rock and the major fertilizer products. The specific production operations which are the principal generators of contaminated waste waters were identified, and the waste water volumes and compositions for each operation were determined wherever possible. The capability of current technology to treat and control the contaminated waste waters generated by the fertilizer industry was evaluated. Problem areas where additional research and development effort is needed to provide adequate control of waste water discharge were identified.

278. Bauer, S. B.
1974. Heavy metals in lakes of the Coeur d'Alene River, Idaho. Master's thesis. Univ. Idaho, Moscow. 66 p.

Heavy metal concentrations were measured in the water, sediments, and fish of nine small lakes located along the main stem of the Coeur d'Alene River. Mining wastes have been discharged into this drainage since the 1890's. Concentrations of dissolved metals were low in the lakes and did not differ significantly from lake to lake. Zn, Cu, Cd, Pb, Cs, and Sb have accumulated in lake sediments. The concentrations of these metals varied in sediments from lake to lake, and within each lake concentrations were highest at stations close to the river.

279. Bogner, J. E., and D. O. Johnson.
1977. Environmental control technology program studies at Argonne National Laboratory: surface mine effluents. 10 p. Argonne National Lab., Ill. [Available NTIS as CONF-7710101-4.]

The chemical quality of surface waters in areas characterized by coal strip mining is the result of both local and regional factors, including composition of coal, overburden, and underclay; mobility of selected chemical constituents in rocks, sediments, and mine soils; activity of chemoautotrophic bacteria; mining and reclamation methods and equipment; density of mining operations in a given watershed; seasonal fluctuations in regional stream discharges; and control technologies implemented to treat mine effluents. The major problems associated with mine effluents in the eastern region are acid mine drainage, generated by the oxidation and subsequent hydrolysis of iron disulfide minerals, and high concentrations of dissolved metals and suspended solids. Control technologies commonly utilized to ameliorate these problems include (1) the addition of alkaline reagents such as hydrated lime, soda ash, or sodium hydroxide to neutralize the acids and promote the precipitation of dissolved metals; and (2) the construction of settling ponds to promote the sedimentation of suspended solids.

280. Bolter, E., and N. H. Tibbs.
1970. Impact of lead-zinc mining on the quality and ecology of surface waters in southeast Missouri. 84 p. Water Resour. Res. Center, Rolla, Mo. [Available NTIS as PB-1974 531.]

The background concentrations were determined for copper, lead, and zinc in the streams of the Viburnum Trend or New Lead Belt of Southeast Missouri. Analytical methods were developed for atomic absorption spectroscopy. These methods initially consisted of coextraction of copper, lead, and zinc using the APDC/MIBK system, and finally of extraction of copper by APDC/MIBK and direct analysis of lead and zinc using the newly developed "sampling boat" technique. The data obtained from these analyses were arranged in histograms and critically analyzed. The background concentrations were established to be 4 to 6 ppb for all three elements. Methods are presented for identifying both short term and long term contamination by using the data distributions. The data distributions were not useful for geochemical prospecting under the studied geological conditions.

281. Bolter, E., and N. H. Tibbs.
1971. Water geochemistry of mining and milling retention ponds in the New Lead Belt of Southeast Missouri. 40 p. Water Resour. Res. Center, Rolla, Mo. [Available NTIS as PB-204 889.]

The heavy metal content and other geochemical data of the mine and mill waters of two mining operations in the "New Lead Belt" of southeastern Missouri were determined and the efficiency of retention ponds in reducing high metal concentrations was investigated. The mine waters from two mines of this mining district, which is the largest lead producer in the world, showed a heavy metal content of less than 6 ppb copper, 66 ppb lead, and 37 ppb zinc. The heavy metal content from the mill effluents was reduced to values similar to mine water, when the pond sizes were large enough. The concentrations of calcium, magnesium, sodium, and potassium, and pH allow the tracing of mine water in the streams. The retention ponds are not entirely efficient in preventing transport of metal rich rockflower in the streams.

282. Brown, A., and others.
1977. Water management in oil shale mining, vol. II, appendices. 318 p. Golder Associates, Inc., Kirkland, Wash. [Available NTIS as PB-276 086/6WN.]

283. Colorado State University.
1971. Water pollution potential of spent oil shale residues. U.S. Environ. Protect. Agency, EPA Document-Grant WO. 14030 EDB, 116 p. Washington, D.C.

284. Dalton, Dalton, Little, Newport.
1977. Water pollution from mining activities. 72 p. Sixth Dist. Counc. of Government, Rapid City, S.Dak.

285. Dames and Moore.
1976. Final report: water quality data at selected active placer mines in Alaska. 49 p. Calspan Corporation, Buffalo, N.Y.

Current Environmental Protection Agency (EPA) effluent criteria pertaining to the placer mining industry have been protested by the Alaska Placer Mining Committee and the Alaska Miners Association as being impractical. Subsequent to these protests, the EPA has initiated a review of the current criteria and contracted Calspan Corporation to collect data from placer mining operations in Alaska. Calspan, in turn, subcontracted Dames and Moore's Fairbanks office to conduct field surveys in August 1976. The information generated by this field work, and data presented in this report are based on Calspan's requirements for data collection.

286. Environmental Protection Agency.
1975. Water quality impacts of uranium mining and milling activities. 188 p. Environ. Protect. Agency, Region IV, Dallas, Tex., Report No. EPA 1906/9-75/002.

Ground water in the study area is affected by mining and waste disposal associated with mining and milling. Contamination appears in close proximity to the mining and milling centers with the exception of more widespread selenium contamination of shallow ground water adjacent to the United Nuclear-Homestake Partners Mill. Contamination of municipally operated water supplies in the study area is not evident. Potable supplies derived from mine water at four industrial sites exceed acceptable limits for selenium in drinking water. Three such systems exceed limits for Radium 226. Recommendations developed are designed to assist the state in future regulation of uranium mining and milling for the purpose of safeguarding public health and insuring future environmental quality.

287. Environmental Protection Agency.
1971. Evaluation of the impact of the Mines Development, Inc. mill on water quality conditions in the Cheyenne River. 51 p. Environ. Protect. Agency, Reg. VIII, Denver, Colo. [Available NTIS as PB-255 270/IST.]

An intensive water quality study of the Cheyenne River and the tributary stream, Cottonwood Creek, in the environs of the Mines Development mill located at Edgemont, S.Dak., was conducted. The objectives of the study were to determine and evaluate: (1) water quality conditions in Cottonwood Creek and the Cheyenne River during a period of dry weather flow; (2) chemical and radioactivity loadings (mas/day) on Cottonwood Creek and the Cheyenne River as the result of seepage from mill ponds; and (3) radioactivity levels in the water, biota, and bottom sediment of Angostura Reservoir.

288. Environmental Protection Agency.
1972. Impact of the Schwartzwalder Mine on the water quality of Ralston Creek, Ralston Reservoir, and Upper Long Lake. 40 p. Tech. Invest. Br., Environ. Protect. Agency, Denver, Colo. [Available NTIS as PB-255 604/IST.]

Considering the magnitude of radioactivity concentrations in Ralston Creek and use of the stream as a primary water source for two water supply reservoirs--Ralston Reservoir and Upper Long Lake, EPA Region VIII initiated a limiting monitoring effort to supplement the state water board program. This monitoring activity extended over the period of May through September 1972. Emphasis was placed on eliminating critical data voids; that is, radioactivity concentrations in the waters of Ralston Reservoir and Upper Long Lake. In addition to the grab water samples collected from these impoundments, sample collection included the mine effluent, water and bottom sediment samples from the two impoundments and Long Lake ditch, and bottom sediment samples from the two impoundments.

289. Environmental Protection Agency.
1975. Development document for interim final effluent limitations guidelines and new source performance standards for the minerals for the construction industry, vol. I. Mineral mining and processing industry. 284 p. Effluent Guidelines Div., Environ. Protect. Agency, Washington, D.C. [Available NTIS as PB-274 593/3ST.]

This document presents the findings of an extensive study of selected minerals in the Minerals for the Construction Industry segment of the mineral mining industry for the purpose of developing effluent limitations guidelines for existing point sources and standards of performance and pretreatment standards for new sources, to implement sections 301, 304, 306 and 307 of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1551, 1314, and 1315, 86 Stat. 816 et. seq.) (the "Act"). Based on the application of best practicable technology currently available, six of the nine production subcategories (comprising 15 minerals) under study can be operated with no discharge of process generated waste water pollutants to navigable waters. With the best available technology economically achievable, eight of the nine production subcategories can be operated with no discharge of process generated waste water pollutants to navigable waters. No discharge of process generated waste water pollutants to navigable waters is achievable as a new source performance standard for all production subcategories except mica, wet benefication process with ceramic grade clay as a byproduct. Supporting data and rationale for development of the proposed effluent limitations guidelines and standards of performance are contained in this report.

290. Gale, W. F., T. V. Jacobsen, and K. M. Smith.
1976. Iron, and its role in a river polluted by mine effluents. Proc. Penn. Acad. Sci. 50(2):182-195.

291. Garinger, L. E.
1977. The regulation of water use in placer mining in the Yukon Territory. In Second Annu. Convention, Alaska Miners Assoc., Proc., Anchorage. p. 14-16.

Experience in the Yukon Territory has been that working closely and communicating with the placer miners and the environmental agency has resulted in a realistic environmental approach. Fish do exist in conjunction with controlled placer mining. Fish have reestablished their population in mined out streams. Some mines in permafrost regions must have unrestricted usage of water in order to exist economically. Unsophisticated settling/filtration facilities can be provided to minimize silt loading on the streams.

292. Germanov, A. I., S. G. Batulin, G. A. Volkov, and others.
1958. Some regularities of uranium distribution in underground waters. Proc., 2d U.N. Int. Conf., Peaceful Uses Atomic Energy, Geneva 2:161-177.

293. Gries, J. P., and P. H. Rahn.
1974. The geochemistry of certain mine and spring waters, western South Dakota. 40 p. S.Dak. Sch. Mines Technol., Rapid City. [Available NTIS as PB-239 829/5ST.]

Fourteen inactive or abandoned gold-silver, lead-silver, or lead-zinc mines were located in the Northern Black Hills which discharge water from their portals or shaft collars. Some discharge fairly evenly throughout the year; some show high seasonal variation; and some drain only during the spring and early summer months. Determinates made include volume of discharge, water temperature, hydrogen ion concentration (pH), specific conductance, and total iron. Where significant discharge entered directly into a stream, measurements were made of the stream water above and below the point of entry of the mine drainage. The only mine workings to show discharges with low pH and high total iron were those with generally very small flow (less than 5 gal/min) from workings developed in highly pyritized porphyry or schist. Large discharges, regardless of rock type, were potable as far as pH, iron, and total dissolved solids were concerned. Effects of these discharges upon streams large enough to support aquatic life were negligible.

294. Grove, D. B., R. L. Miller, L. F. Konikow, and others.
1979. Hexavalent chromium in ground and surface waters near Telluride, Colo. 16 p. U.S. Geol. Surv. open file rep., Jan. 1979.

Data showing the results of 39 ground-water and 30 surface-water samples analyzed for hexavalent chromium are presented. Most samples were taken within the Telluride, Colo., city limits during October 1978. Sixty-three percent of the ground-water samples contained more than 50 micrograms per liter of hexavalent chromium. Twenty-one percent of the surface-water samples contained more than 50 micrograms per liter of hexavalent chromium. Ground-water concentrations range from 0 to 2,700 per liter and surface-water concentrations range from 0 to 160 micrograms per liter.

295. Hallowell, J. B., J. F. Shea, G. R. Smithson, Jr., and others.
1973. Water-pollution control in the primary nonferrous-metals industry, vol. I. Copper, zinc, and lead industries. 173 p. Battelle Columbus Labs., Ohio. [Available NTIS as PB-229 466/8ST.]

The contents of the final reports (two volumes) include: the identification of process steps using water and/or generating wastewater; the amounts of water used for various purposes; recirculation rates; amounts of wastewaters; specific or characteristic substances in wastewaters; the prevalence of wastewater treatment practice, methods, and costs; current treatment problems; and plans for future practices of recirculation of wastewater treatment. Metals included are copper, lead, zinc, and associated byproducts (arsenic, cadmium, silver, gold, selenium, tellurium, sulfuric acid, salts, and compounds), mercury (primary), gold and silver, aluminum, molybdenum, and tungsten. The information includes detailed processing descriptions and flowsheets, tabulations of quantities of water, discharge water quantities and analyses, and water treatment costs.

296. Hallowell, J. B., J. F. Shea, G. R. Smithson, Jr., and others.
1973. Water-pollution control in the primary nonferrous-metals industry, vol. II. Aluminum, mercury, gold, silver, molybdenum, and tungsten. 116 p. Battelle Columbus Labs., Ohio. [Available NTIS as PB-229 467/6ST.]

The treatment needs of the aluminum industry relate to common types of industrial wastewater such as cooling tower blowdown and neutralization products, and the specialized need to remove or recover fluoride ion components from fume scrubbers at smelters. The primary mercury industry, by virtue of a current air pollution control problem, may require increased measures of water pollution control associated with air emission control equipment or new processing methods. The primary molybdenum industry has taken or is designing effective methods of water pollution control ranging from isolated water systems to changes in flotation reagent concentrations. Plants processing refractory metal concentrates to end products generally are associated with municipal water systems and show high materials recoveries with concurrent close control and careful segregation of wastewater streams. Neutralization with filtration of acid wastes is a common practice of the plants surveyed. The small amount of information available for the primary gold and silver industries shows greatly differing practices, ranging from zero discharge in arid climates to problems with mercury and cyanide contents in wastewaters.

297. Hardley, M. G., and others.
1974. Water resources problems and solutions associated with the New Lead Belt of southeastern Missouri. In Water resources problems related to mining. R. F. Hadley and D. T. Snow, eds. Am. Water Resour. Assoc., Minneapolis, Minn., Proc. 18:109-122.

298. Harriss, R. C., and others.
1972. Effect of pollution on the marine environment: a case study. In Coastal Zone Pollution Management Symposium Proc. p. 249-264. B. L. Edge, ed. [Charleston, S.C., Feb. 21-22.]

299. Havlik, B., J. Grafova, and B. Nycova.
1968. Radium liberation from uranium ore processing mill waste solids and uranium rocks into surface streams. (I) The effect of different pH of surface waters. Health Phys. 14:417-422.

300. Hird, J. M.
1971. Control of artesian ground water in strip mining phosphate ores, eastern North Carolina. Am. Inst. Mining, Metallurgical, and Petroleum Eng., Soc. Mining Eng., Trans. 250(2):149-156.

Control of artesian ground water has played an important role in the development of Texas Gulf Sulphur's phosphate mining venture in eastern North Carolina. To facilitate dry mining methods, 60 mgd of fresh water is pumped through wells from a limestone aquifer underlying the uniform flat-lying ore section. High volume pumping has lowered water levels in water wells over a large area in the Coastal Plain without detrimental effects on water quality in the aquifer. An intricate observation well system is monitored regularly over the wide area of pumping effect to ensure that gradient reversals have not caused slat water encroachment.

301. Horton, J. O.
1974. Water for energy. Am. Mining Congr., Washington, D.C.

Identifies supply problems in upper Colorado River Basin, Northern Great Plains, and upper Missouri River Basins.

302. International Minerals and Chemical Corporation.
1978. Water in the bank - an innovative recharge approach. 12 p. Int. Min. and Chem. Corp., Lakeland, Fla.

The International Minerals and Chemical Corporation in conjunction with the southwest Florida Water Management District, the Floridan Department of Pollution Control, and the U.S. Geological Survey has extensively researched the problem of diminishing water supply in Florida. The research resulted in an innovative solution: recharge wells. This pamphlet presents the basics of the problem and the solution.

303. Jarrett, B. M., and R. G. Kirby.
1978. Development document for the effluent limitations and guidelines for the ore mining and dressing point source category, vol. I. 424 p. Effluent Guidelines Div., Environ. Protect. Agency, Washington, D.C. [Available NTIS as PB-286 520/2ST.]

To establish effluent limitation guidelines and standards of performance, the ore mining and dressing industry was divided into 41 separate categories and subcategories for which separate limitations were recommended. This report deals with the entire metal-ore mining and dressing industry and examines the industry by 10 major categories: iron ore; copper ore; lead and zinc ores; gold ore; silver ore; bauxite ore; ferroally-metal ores; mercury ores; uranium, radium and vanadium ores; and metal ores, not elsewhere classified (ores of antimony, beryllium, platinum, rare earth, tin, titanium, and zirconium). The subcategorization of the ore categories is based primarily upon ore mineralogy and processing or extraction methods employed; however, other factors (such as size, climate or location, and method of mining) are used in some instances. With the best available technology economically achievable, facilities in 21 of the 41 subcategories can be operated with no discharge of process wastewater to navigable waters. No discharge of process wastewater is also achievable as a new source performance standard for facilities in 21 of the 41 subcategories.

304. Jennett, J. C., and M. G. Hardie.
1974. Impact of lead mining and milling operations on stream water quality in southeast Missouri. In Proc., 2d Annu. Trace Contam. Conf. [Pacific Grove, Calif.]. p. 172-182. [Available NTIS as TID-4500-R62.]

The investigations summarized were performed in order to: (1) evaluate the effects which the development of the world's largest lead mining district, known as the New Lead Belt or Viburnum

Trend of southeast Missouri, would produce on the quality of the streams draining the Clark National Forest area surrounding these operations; (2) to evaluate the role which these water systems play in the transport of heavy metals through and out of the forest ecosystem; and (3) where possible, to explore techniques for improving the water quality of the region. Data in tabular and graphical form are appended.

305. Johnston, R. S., and R. W. Brown.
1979. Hydrologic aspects related to the management of alpine lands. In Special management needs of alpine ecosystems. p. 66-75. D. A. Johnson, ed. Soc. Range Manage, Range Sci. Series No. 5.

306. Kaufmann, R. F., and J. D. Bliss.
1977. Effects of phosphate mineralization and the phosphate industry on Radium-226 in ground water of central Florida. 27 p. Office of Radiation Programs, Las Vegas, Nev. [Available NTIS as PB-274 116/3ST.]

Principal U.S. phosphate production is from central Florida where mining, processing, and waste disposal practices intimately associate the industry with water resources. Available Radium-226 data from 1966 and from 1973-1976 were statistically analyzed to characterize radium in the water table, Upper Floridan, and Lower Floridan aquifers. Mined and unmined mineralized areas and nonmineralized areas in the primary study area in Polk, Hardee, Hillsborough, Manatee, and De Soto counties were studied. Log-normal probability plots and nonparametric statistical tests (Mann-Whitney, Kruskal-Wallis, Kolmogorov-Smirnov, simultaneous multiple comparison) were used to analyze for central tendency, variance, and significant difference as functions of time, depth, and location.

307. Kaufmann, R. F., G. G. Eadie, C. R. Russell, and others.
1977. Effects of uranium mining and milling on ground water in the Grants Mineral Belt, New Mexico. 14 p. Office of Radiation Programs, Las Vegas, Nev. [Available NTIS as PB-262 819/6ST.]

Ground-water contamination from uranium mining and milling results from the infiltration of mine, mill, and nonexchange plant effluents containing elevated concentrations of radium, selenium, and nitrate. Available data indicate that radium concentrations are generally about several picocuries/liter (pCi/l); 100 to 150 pCi/l appear in the effluents of operating mines. The discharge of such highly contaminated mine effluents to streams and seepage from tailings ponds creates a long-lived source of ground-water contamination. Seepage of mill tailings at two active mills ranges from 126,000 to 491,000 m^3/yr and, to date, has contributed an estimated 2,400 curies of uranium, radium, and thorium to the ground-water reservoir. Radium, selenium, nitrate, and to a lesser extent, uranium, are of most value as indicators of ground-water contamination.

308. Kaufmann, R. F., G. G. Eadie, C. R. Russell, and others.
1975. Summary of ground-water quality impacts of uranium mining and milling in the Grants Mineral Belt, New Mexico. 81 p. Office of Radiation Programs, Las Vegas, Nev. [Available NTIS as PB-247 282/7ST.]

Ground-water contamination from uranium mining and milling results from the infiltration of radium-bearing mine, mill, and ion-exchange plant effluents. Radium, selenium, and nitrate were of most value as indicators of contamination. In recent years, mining has increased radium in mine effluents from several picocuries/liter (pCi/l) or less, to 100-150 pCi/l. The shallow aquifer in use in the vicinity of one mill was grossly contaminated with selenium, attributable to the mill tailings. Seepage from two other mill tailings ponds averages 67,400,000 liters per year and, to date, has contributed an estimated 1.1 curies of radium to ground water. At one of these an injection well was used to dispose of over 3,400,000,000 liters of waste from 1960-1973. The wastes have not been properly monitored and have apparently migrated to more shallow potable aquifers. No adverse impacts on municipal water quality in Paguate, Bluewater, Grants, Milan, and Gallup were observed.

309. Lawrence, J., and H. W. Zimmermann.
1977. Asbestos in water: mining and processing effluent treatment. Water Pollution Contr. Fed. J. 49(1):156-160.

310. Magorian, T. R., K. G. Wood, J. G. Michalovic, and others.
1974. Water pollution by thallium and related metals. 196 p. Calspan Corp., Buffalo, N.Y. [Available NTIS as PB-253 333/9ST.]

A sampling program was planned and carried out to elucidate the extent of movement and concentration of thallium and related metals in physical and biological compartments of the aquatic environment. During this project, Calspan personnel sampled smelter and mill wastewater outfalls, receiving water, slag heaps, tailings ponds and streams, and coal-burning facility fly ash dumps. The amount of heavy metals in sediment is greater at any given time than that dissolved in water, and hence floodwater erosion of particulate matter presents a hazard. Up to 17 percent lead, 0.1 percent cadmium, and 5 ppm thallium were found in sediments of streams used for irrigation and drinking water below copper and zinc extractive industries in high runoff regions. Ground-water infiltration in the Northwest and Ozarks provides mine drainage water which is used in mills and/or concentrators. This volume of water transports toxic wastes into naturally erosive bottom sediments, thereby contaminating the food chain. Heavy metal concentrations in water are higher in the fall at low water following benthic accumulations during the growing season. Metal pickup by algae was measured in the laboratory. Procedures for detecting and measuring the amount of thallium by atomic absorption in the presence of concentrations of chloride and other ions were developed.

311. Miller, J. A., G. H. Hughes, and R. W. Hull.
1978. Impact of potential phosphate mining on the hydrology of Osceola National Forest, Florida. 169 p. U.S. Geol. Surv., Tallahassee, Fla. [Available NTIS as PB-278 853/7ST.]

Potentially exploitable phosphate deposits underlie part of Osceola National Forest. Hydrologic conditions in the forest are comparable with those in nearby Hamilton County, where phosphate mining and processing have been ongoing since 1965. Given similarity of operations, hydrologic effects of mining in the forest are predicted. Flow of stream(s) receiving phosphate industry effluent would increase somewhat during mining, but stream quality would not be greatly affected. Local changes in the configuration of the water table and the quality of water in the surficial aquifer will occur. Lowering of the potentiometric surface of the Floridan aquifer because of proposed pumpage would be less than 5 feet at nearby communities. Floridan aquifer water quality would be appreciably changed only if plant effluent were discharged into streams which recharge the Floridan through sinkholes. The most significant hydrologic effects would occur at the time of active mining; long-term effects would be less significant.

312. Mink, L. L., A. T. Wallace, and R. E. Williams.
1971. Effects of industrial and domestic effluents on the water quality of the Coeur d'Alene River Basin. Idaho Bur. Mines and Geol., Pamphlet 49, 94 p. Moscow, Idaho.

313. Mohammad, O. M. J.
1977. Evaluation of the present and potential impacts of open pit phosphate mining on ground-water resource systems in southeastern Idaho phosphate field. Ph.D. diss. Univ. Idaho, Moscow. 179 p. [Diss. Abstr. Int. 38/03-B:1109.]

314. Morgan, J. M., Jr.
1959. A stream survey in the uranium mining and milling area of the Colorado Plateau. 354 p. The Johns Hopkins Univ., Baltimore, Md.

315. National Enforcement Investigations Center.
1975. Impacts of uranium mining and milling on surface and potable waters in the Grants Mineral Belt, New Mexico. 85 p. Natl. Enforcement Invest. Cent., Denver, Colo. [Available NTIS as PB-255 583/7ST.]

On September 25, 1974, NMEIA requested EPA Region VI to conduct a survey of water-pollution sources and surface and ground-water quality in the Grants Mineral Belt. Studies conducted from February 24 to March 6, 1975, included industrial waste source evaluation, potable water sampling, and limited stream surveys by National Enforcement Investigations Center (NEIC) and ground-water evaluations by ORP-LVF. This report presents the findings of analyses of surface water streams, potable water supplies, and industrial discharges. Appendix C contains raw data for all samples collected during the survey and analyzed by NEIC. The NEIC analysis, when combined with the ORP-LVF report, will present an overall study of water quality in the Grants Mineral Belt.

316. National Field Investigations Center.
1973. Reconnaissance study of radiochemical pollution from phosphate rock mining and milling. 106 p. Natl. Field Invest. Cent., Denver, Colo. [Available NTIS as PT-241 242/7ST.]

A reconnaissance study of the phosphate mining and milling industry was necessary to investigate the magnitude of radiochemical pollution to receiving waters. This report describes the findings of the study and other related problems associated with processing of phosphate fertilizers, such as air pollution, ground-water contamination, possible deleterious consequences of fertilizer use, effects on other receiving water uses, including shellfish and drinking water supplies, and the use of byproduct material in the construction industry. Throughout the report a comparison has been made of reconnaissance sampling results with promulgated radiochemical standards and guidelines. Pollution control and analysis and water quality data are also discussed.

317. National Limestone Institute, Inc.
1977. Limestone purifies water. 33 p. Natl. Limestone Inst., Inc., Fairfax, Va.

A review of the scientific and technical materials available reveals that rainfall runoff involving limestone operations is nondeleterious to water and is, in fact, beneficial to the aquatic environment. This fact makes limestone different from the mining process for any other mineral substance, including coal, metallic ores, granite, traprock, clay, and sand or gravel. In the face of deteriorating water quality, due in part to acidic rainfall and coal mine acid drainage, limestone is a beneficial additive to water.

318. Norbeck, P. N., L. L. Mink, and R. E. Williams.
1974. Ground-water leaching of jib tailing deposits in the Coeur d'Alene district of northern Idaho. In Water resources problems related to mining. p. 149-157. Am. Water Resour. Assoc., Minneapolis, Proc. 18, 236 p.

319. Probstein, R. F., and H. Gold.
1978. Water in synthetic fuel production: the technology and the alternatives. 296 p. The MIT Press, Cambridge, Mass.

A comprehensive text on water use, water consumption, and requirements for synthetic fuel production, including water uses and needs in mining. Technology and alternatives are discussed.

320. Proctor, P. D., and B. Sinha.
1978. Heavy metal mobilization, transportation and fixation in the Fredericktown Co-Ni-Cd-Cu-Zn-Pb providence to Lake Wappapello, Missouri as related to surface waters, stream sediments and stream algae. 46 p. Missouri Water Resour. Res. Cent., Rolla. [Available NTIS as PB-282 371/4ST.]

In a unique geologic occurrence and setting in the central United States, cobalt, nickel, cadmium, copper, zinc, and lead ores have been mined and milled from the Fredericktown metalliferous province in southeast Missouri. Major objectives of this study were to determine the heavy metal content in the river waters, stream sediments, and stream algae in drainage areas affected by mining and milling operations in the Fredericktown area. A second major objective was to compare the metal contents of these three media with the same media in an area not known to contain significantly anomalous contents of heavy metals, yet in a Precambrian rock terrain. A third objective is to compare the heavy metal contents in stream sediments,

stream waters, and algae near the mouth of the St. Francis River where it enters Lake Wappapello with areas of Stouts Creek and Fredericktown to the north to determine the fate of heavy metals in this more stable water environment.

321. Public Health Service.
1970. Radium monitoring network. Div. of Water Supply and Pollution Contr., Public Health Serv., Denver, Colo., Data Release Number 1-16, 32 p. [Available NTIS as PB-260 231/6ST.]

The 16th data release report provides Radium-226 and uranium sampling results that supplement data from 15 previous reports dated October 1962 through July 1969. The tabular data indicate evidence of radium and uranium below recommended concentration levels from analysis of composite water samples at stations of the Radium Monitoring Network of the Colorado River Basin Water Quality Control Project. The network is a surveillance system consisting of continuous surface water sampling at 27 locations throughout the basin. It assays the radiological content of river water over the entire basin.

322. Public Health Service.
1963. Shiprock, New Mexico uranium mill accident of August 22, 1960. 66 p. Div. of Water Supply and Pollution Control, Public Health Serv., Denver, Colo. [Available NTIS as PB-260 237/3ST.]

The conduct of field investigations of this incident, in which a raffinate waste liquor holding pond wall ruptured, is reviewed along with its effect on downstream water users. Chemical and physical data for river water samples leave little doubt that the mill wastes reached the San Juan River in considerable quantity by the following day. The need for stringent prevention measures is discussed.

323. Public Health Service.
1961. Stream surveys in vicinity of uranium mills. III. Area of Uravan, Slick Rock, and Gateway, Colorado-August 1960. 38 p. Div. of Water Supply and Pollution Control, Public Health Serv., Denver, Colo. [Available NTIS as PB-260 289/4ST.]

This is a report of one of three short-term field studies carried out in the vicinity of uranium processing mills in western Colorado and eastern Utah during August 1960. These studies were the initial undertaking of the Colorado River Basin Water Quality Control Project and were made for the purpose of determining the pollutional constituents contained in uranium mill discharges and the effects of these discharges on receiving waters in certain specific areas of the Colorado River Basin. The results of the other studies are contained in reports of the Colorado River Basin Project.

324. Public Health Service.
1962. Stream surveys in vicinity of uranium mills. IV. Area of Shiprock, New Mexico - November 1960. 33 p. Div. of Water Supply and Pollution Control, Public Health Serv., Denver, Colo. [Available NTIS as PB-260 290/2ST.]

The findings of an 8-day field survey of stream conditions in the San Juan River below Shiprock, New Mexico, are reported. The survey followed a brief investigation in connection with the accidental release of a relatively large volume of highly toxic acid waste from the Kerr-McGee Oil Industries uranium mill at Shiprock in August 1960. Residual effects and long-term conditions are evaluated. Water quality conditions were evaluated on the basis of radiological, chemical, and biological data collected in the study area.

325. Purtyman, W. D., C. L. Wienke, and D. R. Dreesen.
1977. Geology and hydrology in the vicinity of the inactive uranium mill tailings pile, Ambrosia Lake, New Mexico. 36 p. Los Alamos Sci. Lab., N.Mex. [Available NTIS as LA-6839-MS.]

326. Rouse, J. V.
1974. Radiochemical pollution from phosphate rock mining and milling. In Water resources problems related to mining. p. 65-71. R. F. Hadley and D. T. Snow, eds. Am. Water Resour. Assoc., Minneapolis, Minn., Proc. 18, 236 p.

327. Ryan, R. K., and P. G. Alfredson.
1976. Liquid wastes from mining and milling of uranium ores: a laboratory study of treatment methods. 43 p. Aust. Atomic Energy Comm. Res. Establishment, Lucas Heights. [Available NTIS as AAEC/E-394.]

328. Ryck, F., Jr., and J. R. Whitley.
1974. Pollution abatement in the lead mining district of Missouri. Purdue Univ. Eng. Bull. Eng. Ext. Serv. 145, p. 857-863.

This report documents biological conditions in three streams prior to and after the start of lead mining and milling, and evaluates the effectiveness of mill effluent recycling and stream channel modification as pollution abatement techniques.

329. Ryon, A. D., F. J. Hurt, and F. G. Seeley.
1977. Nitric acid leaching of radium and other significant radionuclides from uranium ores and tailings. Oak Ridge Natl. Lab., Rep. ORNL/TM-5944, 37 p. Oak Ridge, Tenn.

330. Sceva, J. E.
1973. Water quality considerations for the metal mining industry in the Pacific Northwest. 83 p. U.S. Environ. Protect. Agency, Seattle, Wash. [Available NTIS as PB-226-995.]

The paper includes sections on water quality considerations at active mines (including recommended practices); water quality considerations at abandoned mines (including recommended practices for closing a mine); and guidelines for construction of mine roads.

331. Scott, R. L., and R. M. Hays.
1975. Inactive and abandoned underground mines. Water pollution prevention and control. 322 p. Michael Baker, Jr., Inc., Beaver, Penn. [Available NTIS as PB-258 263/3ST.]

Underground mining operations across the United States produce a number of environmental problems. The foremost of these environmental concerns is acid discharges from inactive and abandoned underground mines that deteriorate streams, lakes, and impoundments. Waters affected by mine drainage are altered both chemically and physically. This report discusses in Part I the chemistry and geographic extent of mine drainage pollution in the United States from inactive and abandoned underground mines; underground mining methods; and the classification of mine drainage control techniques. Control technology was developed mainly in the coal fields of the Eastern United States and may not be always applicable to other regions and other mineral mining. Available at-source mine drainage pollution prevention and control techniques are described and evaluated in Part II of the report and consist of five major categories: (1) water infiltration control; (2) mine sealing; (3) mining techniques; (4) water handling; and (5) discharge quality control. This existing technology is related to appropriate cost data and practical implementation by means of examples.

332. U.S. Environmental Protection Agency.
1975. Water quality impacts of uranium mining and milling activities in the Grants Mineral Belt, New Mexico. U.S. Environ. Protect. Agency, Dallas, EPA/906/9-75/002, 188 p. [Available NTIS as PB-251/470/1WN.]

333. U.S. Geological Survey.
1977. Effects of abandoned lead and zinc mines and tailings piles on water quality in the Joplin area, Missouri. 55 p. U.S. Geol Surv., Rolla, Mo. [Available NTIS as PB-274-392/OGA.]

Dissolved zinc concentrations average 9 400 micrograms/liter in water from abandoned lead and zinc mines, some of which discharge at the surface. Contamination of the shallow aquifer (cherty limestones) by the highly mineralized mine water is limited to the immediate mining area. The quality of water in the deep aquifer (cherty dolomites and sandstone) is generally excellent. Dissolved zinc concentrations average 16 000 micrograms/liter in runoff from tailings areas. During a summer storm, however, runoff from a 7-acre tailings area contained maximum dissolved zinc, lead, and cadmium concentrations of 200 000; 400; and 1 400 micrograms/liter, respectively. Mine-water discharges increase dissolved zinc concentrations in receiving streams from a background of about 50 micrograms/liter to about 500 micrograms/liter during periods of low flow. The higher concentrations are sustained during high flow by runoff from the tailings areas. Deposition of tailings on stream bottoms increases zinc concentrations in bottom material from a background of about 100 micrograms/gram to about 2 500 micrograms/gram and increase lead concentrations in bottom material from about 20 micrograms/gram to about 450 micrograms/gram.

334. U.S. Geological Survey.
1976. Water-resources investigations of the U.S. Geological Survey in the major coal and oil shale areas of Wyoming, 1975-76. 43 p. U.S. Geol. Surv., Cheyenne, Wyo., open-file report.

335. U.S. Geological Survey.
1976. Hydrologic studies by the U.S. Geological Survey in oil-shale areas of Colorado, Utah, and Wyoming, 1976. 88 p. U.S. Geol. Surv., Cheyenne, Wyo., open-file report, February.

336. Van Zandt, T.
1975. Water for oil shale: some institutional alternatives for water allocation in arid rural regions. Water Resour. Bull. 11(6):1181-1186.

337. Water for Energy Management Team.
1974. Water for energy in the upper Colorado River Basin. 71 p. Dep. of the Interior, Eng. and Res. Center, Denver, Colo.

338. Weeks, J. B.
1976. Ground-water problems with oil shale mining in the Piceance Basin. Water Spectrum 8(1):8-14.

339. Weeks, J. B., and others.
1975. Simulated effects of oil shale development on the hydrology of Piceance Basin, Colorado. U.S. Geol. Surv., Prof. Pap. 908, 84 p. Reston, Va.

340. West, S. W.
1972. Disposal of uranium mill effluent by well injection in the Grants area, Valencia County, New Mexico. U.S. Geol. Surv. Prof. Pap. 386-D, 28 p.

341. Western Technology and Engineering, Inc.
1978. Mining and minerals fuels development in Montana's 208 study area: implication to water quality, final draft prepared for statewide 208 program. 191 p. Prepared for Mont. Dep. Health and Environ. Sci., Water Qual. Bur., Helena.

342. Wilson, D. W.
1977. Evaluation of regional effects of effluents from uranium production in New Mexico. 13 p. Lawrence Livermore Lab., Calif. Univ., Livermore. [Available NTIS as UCRL-13802.]

The Grants Uranium Region is a 2,600-mile area of north central New Mexico that has produced about 40 percent of all domestic uranium, and holds over one-half of the current reserves. The increasing demand for uranium to fuel commercial nuclear power plants is resulting in rapid growth of the uranium industry and economic, social, and environmental changes are occurring. One of the environmental issues of this region is the concern for eventually

unacceptable levels of air and water pollution from effluents from uranium mill tailings piles. This study addresses these potential impacts in relation to industrial environmental control practices, siting features, and other regional/temporal variables, including rates of production, locations and sizes of new mills, and population distributions.

343. Wixson, B. G., and E. Bolter.
1972. Evaluation of stream pollution and trace substances in the New Lead Belt of Missouri. In Trace substances in environmental health. p. 143-152. D. D. Hemphill, ed. Univ. Missouri, Columbia.

In stream pollution studies carried out in the "New Lead Belt" of southeastern Missouri, data were collected to evaluate the effects of trace substances in wastes of lead-zinc mining operations, the character of individual wastes, and the effectiveness of stabilization lagoons in treating discharges. Samples from mine discharge water, combined mine-mill effluent, lagoon system effluent, and streams below the mine lagoons were taken and compared with control site samples from unpolluted streams. Biological, chemical, and physical parameters were evaluated, along with trace metal determinations of lead, zinc, and copper. Mining wastewater contains carbon dioxide and sufficient phosphorus to combine with nitrogen present in stream water and cause undesirable benthic growths in bacterial-algal mats. Recommendations include recycling of milling wastewater and separate treatment of mine discharge water; treatment of tailings wastewater and baffled or submerged discharge outlets; and final treatment lagoons to remove colloidal material, trace substances, and metals by biological treatment.

344. Wixson, B. G., and H. W. Chen.
1970. Stream pollution in the "New Lead Belt" of S.E. Missouri. 23 p. Missouri Water Resour. Res. Cent., Columbia. [Available NTIS as PB-195 285.]

The project studied the effects of lead-zinc mining and milling pollution in the Viburnum Trend or "New Lead Belt" of southeastern Missouri. Results obtained from the project included the following: stream pollution below the mine discharge was mainly due to the growth of large algal mats of oscillatoria and bacteria which appear to result from the discharge of sodium isopropyl xanthate in the milling wastewater; limits were established for the precipitation of lead, zinc, and copper in relationship to pH and other water quality parameters; the amount of fluorides in the streams may be used as an indicator of mining water discharges; new techniques may be used to evaluate organic milling reagents in the water and in the biota; diatoms may be used as biological indicators of mine wastewater effects.

345. Wymore, I. F., W. D. Striffler, and W. A. Berg.
1974. Water requirements for stabilizing and vegetating spent shale in the Piceance Basin. In Surface rehabilitation of land disturbances resulting from oil shale development, executive summary. p. 47-56. C. W. Cook, ed. Colo. State Univ., Fort Collins, Environ. Resour. Cent. Infor. Ser. 11, 56 p.

346. Zellars-Williams, Inc.
1977. Water recirculation system of central Florida phosphate mining. 97 p. Zellars-Williams, Inc., Lakeland, Fla. [Available NTIS as PB-270 359/3ST.]

This report presents a model of water use and recycling at three active central Florida phosphate mines. Water balances for two mines are constructed for two different years to illustrate the effects of seasonal fluctuations and system flexibility. The recirculating water systems of active central Florida mines are used to convey and process the ore, transport and store sand and clay wastes, and reclaim the water for reuse. This preliminary study highlights the complexity and diversity of mine water systems while explaining the basic concepts required for their analysis.

2. ACID MINE DRAINAGE

347. Ciolkosz, E. J., L. T. Kardos, R. C. Cronce, and others.
1978. Soil as a medium for the renovation of acid mine drainage water: part I. Soil-water quality and vegetative responses. 242 p. Dep. Agron., Penn. State Univ., University Park. [Available NTIS as PB 278 161/5ST.]

This study determined the feasibility of using soil as a medium for the renovation of acid mine drainage water. The effects of liming and three levels of irrigation with acid water were studied. Acid water from a stream was applied weekly at three levels to an unlimed and a limed flood plain soil. Soil water samples were collected weekly. The soil water samples and the acid water applied were analyzed for pH, total acidity, conductivity, Al, Fe, Mn, SO_4, Ca, Mg, K, and Na. Perennial ryegrass and tall fescue were planted in separate halves of each experimental unit. During the study, the grasses were measured for yield, height, stand density, and percent cover. Both the unlimed and limed areas initially had considerable capacity for renovating the applied acid water. Liming and the weekly levels of acid water irrigation significantly affected the growth of perennial ryegrass and tall fescue.

348. Ciolkosz, E. J., L. T. Kardos, R. C. Cronce, and others.
1978. Soil as a medium for the renovation of acid mine drainage water: part II. Soil physical and chemical changes. 161 p. Dep. Agron., Penn. State Univ., University Park. [Available NTIS as PB 278 162/3ST.]

Acid coal mine water was applied to a Linden sandy loam soil at various levels. The soil data indicated that the main reactions between the applied water and the soil occurred in the upper part of the soil profile. The cation exchange capacity of the soil appeared to be the most important soil property affecting the renovation of the acid water. The basic cations were removed from the soil in the upper part of the profile and exchanged for H and Al in the water, thus causing the acidity of the soil to increase and the pH of the water to increase. Amounts of Ca and Na in the soil decreased, while the amount of the exchange acidity, K, and Al increased from acid mine water application. The Ca:Mg ratio of the soil decreased as a result of the treatment. Soil temperatures were lower in the irrigated areas than in the unirrigated areas. Apparently the better stand of vegetation in the irrigated area shaded the soil more and thus lowered its temperature.

349. Crane, M.
1974. The use of a fluidized bed electrode for the removal of dissolved iron from acid mine drainage. Ph.D. thesis. New York Univ., New York. 83 p. [Diss. Abstr. Int. 35/08-B:3892.]

350. Cywin, A.
1970. Neutralization of ferrous iron-containing acid wastes. 4 p. U.S. Environ. Protect. Agency, Washington, D.C. [Available NTIS as PB-236 528/6SL.]

The patent describes the neutralization of acid wastewaters containing ferrous iron using limestone in a finely divided state. Substantial amounts of a mixed valence, hydrous iron oxide sludge are recycled back to the dense, easily dewatered sludge to improve handling characteristics.

351. Franco, N. B., and R. A. Balouskus.
1974. Electrochemical removal of heavy metals from acid mine drainage. 97 p. U.S. Environ. Protect. Agency, Environ. Protect. Tech. Series, Proj. EPA-14010-GAO. Washington, D.C. [Available NTIS as PB-232 746/1.]

Laboratory and field studies were conducted to determine the economics of ferrous iron oxidation in a cell containing a bed of conductive particles in the space between the cathode and the anode. The effects of the process on other heavy metals present in acid mine drainage (AMD) and on the character of solids precipitated during treatment of low acidity water were also observed. An 18.9 liter/min (5 gal/min) pilot plant was operated at an actual mine site to evaluate treatment of 40 and 250 ppm ferrous iron AMD at pH levels of 2 and 5. A conventional

aeration system was also included to generate comparative data. Estimates for a 473 liter/min (125 gal/min) plant based on the pilot data for oxidation only indicate that capital and operating costs for electrochemical treatment would be higher than those for aeration by factors of 5 and 1.7, respectively.

352. Fuller, R. H., J. M Shay, R. F. Ferreira, and others.
1978. An evaluation of problems arising from acid mine drainage in the vicinity of Shasta Lake, Shasta County, California. 14 p. Water Resour. Div., U.S. Geol. Surv., Menlo Park, Calif. [Available NTIS as PB-284 667/3ST.]

Streams draining the mined areas of massive sulfide ore deposits in the East and West Shasta Mining Districts of northern California are generally acid and contain large concentrations of dissolved metals, including iron, copper, and zinc. The streams, including Flat, Little Backbone, Spring, West Squaw, Horse, and Town Creeks, discharge into Shasta Lake and Sacramento River and have caused numerous fish kills. The major source of pollution is discharge from underground mines. A secondary source of pollution is streamflow and surface runoff that have passed through mine dumps where the oxidation of pyrite and other sulfide minerals results in the production of acid and the mobilization of metals. Suggested methods of treatment include the use of air and hydraulic sealing of the mines, lime neutralization of mine effluent, channeling of runoff and mine effluent away from mine and tailing areas, and the grading and sealing of mine dumps.

353. Grady, W. C., and D. J. Akers.
1976. Utilization of acid mine drainage treatment sludge. West Virginia Univ., Morgantown, Coal Res. Bur. Sch. Mines Tech. Rep. 132, 20 p.

Acid mine drainage treatment sludge can be used, with little modification, as a neutralizing agent for strip mine soils to aid in revegetation of mined areas. Dried and powdered sludge can be used as a substitute or additive to limestone in rock-dusting underground coal mines. A ceramic structural product can be produced by firing pretreated and preformed sludge to a temperature of 1 250°C. This material has a crush strength in excess of 800 lb/inch. Utilization as cement aggregate and recovery of metals and minerals are also discussed.

354. King, D. L., and J. J. Simmler.
1973. Organic wastes as a means of accelerating recovery of acid strip-mine lakes. 70 p. Missouri Water Resour. Res. Cent., Columbia. [Available NTIS as PB-219 264/9.]

The study determines the role of metals in the natural and accelerated recovery of strip-mine waters from the time of acid formation on the pyrite crystal to the time of lake recovery. A host of acid dissociated ionic species, including iron, sulfate, hydrogen, aluminum, manganese, calcium, and magnesium, and allochthonous organic materials characterize the chemistry of these lakes. The metal buffers are responsible for the long natural recovery times associated with all acid strip-mine lakes. The amount of such buffers depends upon the amount and type of clays and minerals and is dependent on the availability of carbon sources for sulfate reducing bacteria to use as food while they "titrate" the acidity by releasing H_2S to the atmosphere until all buffers are exhausted.

355. Kugatow, M. A.
1977. Mediation of acid strip mine pollution by the attempted inhibition of the iron-oxidizing autotroph, *Thiobacillus ferrooxidans*. D.Ed. thesis. Penn. State Univ. 68 p. [Diss. Abstr. Int. 38/10-B:4597.]

356. Larsen, H. P., and L. W. Ross.
1976. Two-stage process chemically treats mine drainage to remove dissolved metals. Eng. Min. J. 177(2):94-96.

Treatment of mine drainage waters has fast become a necessity for all mining operations, and regulations governing discharge into local waterways can be expected to become even more stringent. One aspect of mine water treatment--removal of dissolved metals--can be accomplished by a two-stage process developed at the Denver Research Institute (DRI). The first stage of

the process treats the waters by lime neutralization to eliminate Fe and Al. A second stage then removes Cu, Zn, Mn, and heavy toxic metals (Hg, Cd, As) by adding sulfide to the waters. The quantitative effects of both stages of treatment can be predicted by a mathematical description based on the equilibrium relations involved.

357. Long, D. A., J. L. Butler, and M. J. Lenkevich.
1977. Soda ash treatment of neutralized mine drainage. 76 p. Gwin, Dobson, and Foreman, Inc., Altoona, Penn. [Available NTIS as PB-272 760/OST.]

Utilization of acid mine drainage (AMD) streams as a source of potable and industrial water has become a major goal of several proposed AMD treatment schemes. From among the various schemes available, the lime neutralization/soda ash softening process was selected for use at Altoona, Penn. The treatment plant, as constructed, has the capability of treating waters from Kittanning Run (acid mine polluted) alone or in combination with waters from other city sources to achieve: (1) neutralization and iron removal to levels satisfactory for stream release, (2) softening to approximately 100 mg/l $CaCO_3$ hardness for municipal use, and (3) softening to a hardness of 200 mg/l $CaCO_3$ or higher to meet industrial use requirements. The objective of this study was to evaluate the technical and economic feasibility of softening neutralized AMD waters by means of the cold lime/soda ash process. The study was conducted full-scale at the Altoona Treatment Plant located near the Horseshoe Curve area of Altoona, Penn. Unit processes employed at the plant consisted of lime neutralization, aeration, settling, soda ash softening, recarbonation, and filtration.

358. McPhilliamy, S. C., and J. Green.
1973. A chemical and biological evaluation of three mine drainage treatment plants. 81 p. Surveillance and Analysis Div., Environ. Protect. Agency, Wheeling, W.Va. [Available NTIS as PB-254 543/4ST.]

Chemical and biological sampling was conducted at three mine drainage treatment plants operating in Washington County, Penn. In addition to the parameters generally associated with mine drainage, 10 additional parameters were included for analysis during three of the four sampling rounds. These metals were manganese, aluminum, calcium, magnesium, cadmium, chromium, copper, lead, nickel, and zinc. They were included in a general attempt to observe the efficiency of a conventional mine drainage treatment plant for the removal or reduction of metals not commonly associated with mine drainage but often present in measurable quantities.

359. Miller, J. D.
1972. Removal of dissolved contaminants from mine drainage. 61 p. Univ. Utah, Salt Lake City. [Available NTIS as PB-214 563/6ST.]

Eleven mill tailing samples from locations throughout the Rocky Mountain region were tested for their effectiveness in removal of dissolved contaminants from mine drainage. The average capacity of the tailings tested was 9.8 mg of iron per gram of tailing with a range of capacities from 6 mg/g to 15 mg/g. From these studies it was concluded that for almost all tailing samples, removal was accomplished mainly due to hydrolytic absorption of metal ions with a small contribution due to the inherent basicity of the tailing. In the other case, removal occurred via reaction with calcareous components of the sample. Continuous column, or stationary bed tests, in the laboratory and in the field, were not nearly as effective. It appears that for effective removal a stirred tank reactor will be required.

360. Montana Department of Natural Resources and Conservation.
1977. Feasibility of silver-lead mine waste manipulation for mine drainage control. 109 p. Mont. Dep. Nat. Resour. and Conserv., Helena. [Available NTIS as PB-276 599/8ST.]

The purpose of the feasibility study, Dry Fork of Belt Creek, Mont., is to examine solutions and methods of abatement of acid mine drainage problems, and recommend a solution. The Galena Creek area in the Dry Fork of Belt Creek drainage contains several old mine tailings piles from which acidic waters emerge. The acidic water has destroyed the aquatic life in Galena Creek and the Dry Fork of Belt Creek as well as ruined the overall esthetic value of both

creeks. Mine dump surface regrading and sealing are recommended as the method of reducing the acidic wastes entering Galena Creek. The top of Block P Mine dump should be sloped so as to allow proper drainage. The top should also be sealed with a bentonite seal, and top soil added to allow revegetation. The bypass pipeline around the Block P dump should be extended to prevent water in Galena Creek from creating seeps in the toe of the dump.

361. Nebgen, J. W., D. F. Weatherman, M. Valentine, and others.
1976. Treatment of acid mine drainage by the alumina-lime-soda process. 105 p. Midwest Res. Inst., Kansas City, Mo. [Available NTIS as PB-259 930/6ST.]

The alumina-lime-soda process is a chemical desalination process for waters in which the principal sources of salinity are sulfate salts. The process has been field tested at the Commonwealth of Pennsylvania's Acid Mine Drainage Research Facility, Hollywood, Penn., as a method to recover potable water from acid mine drainage. The alumina-lime-soda process involves two treatment stages. Raw water is reacted with sodium aluminate and lime in the first stage to precipitate dissolved sulfate as calcium sulfoaluminate. In the second stage, the alkaline water (pH = 12.0) recovered from the first stage is carbonated to precipitate excess hardness. Following carbonation, product water meets U.S. Public Health Service specifications for drinking water. Alumina-lime-soda process economics are influenced most by the cost of sodium aluminate.

362. Olem, H.
1975. The rotating biological contactor for biochemical ferrous iron oxidation in the treatment of coal mine drainage. 85 p. Penn. State Univ., University Park. [Available NTIS as PB-264 534/9ST.]

Pilot scale testing of the rotating biological contactor for the oxidation of ferrous iron in acid coal mine drainage has shown the process to be dependable, efficient, and economically comparable to purely chemical methods of iron oxidation. The 0.5-meter device consisted of four sets of plastic discs affixed to a centralized shaft. As the discs rotated half immersed in flowing mine water, an average iron-oxidizing bacterial population of 70,000 cells per square centimeter colonized the disc surfaces without prior bacterial preseeding or nutrient supplementation. Concentration dependent first order kinetics were established during continuous operation from May 1974 through March 1975 at several hydraulic loading and disc rotation rates. Hydraulic loadings of 2.7 and 5.4 gal/day/ft^2 (0.11 and 0.22 m^3/day/m^2) at optimum disc rotation resulted in the transformation of an average 240 mg/l influent ferrous iron to produce effluents of 2 and 5 mg/l, respectively. Performance was not impaired when operated at mine water temperatures as low as 8°C and the process was shown to recover rapidly when subjected to artificially induced toxicity in the form of a strong disinfectant solution. The process prepared a coal mine drainage containing up to 313 mg/l of ferrous iron for limestone neutralization and subsequent solids precipitation at an estimated operating cost of 4 cents per thousand gallons (1 cent per cubic meter).

363. Pearson, F. H., and J. B. Nesbitt.
1972. Combined treatment of municipal wastewater and acid mine drainage system. 50 p. Inst. for Research on Land and Water Resources, Penn. State Univ., University Park. [Available NTIS as PB-222 936/7.]

Acid mine drainage (AMD), a serious water pollutant in many states, may be an economical source of ferrous iron for the chemical coagulation of municipal wastewater. AMD would then be neutralized by the alkalinity in wastewater. Samples of AMD and raw wastewater were collected from sites in Pennsylvania where AMD was found close to a wastewater treatment plant. The samples were mixed in varying ratios, then processed at controlled pH in a laboratory scale treatment plant that provided flocculation and sedimentation. The optimal pH was 8 for a maximum reduction in phosphorus, ferrous iron, and turbidity. At pH 8 the median reduction in total phosphorus was 95 percent when the molar ratio of ferrous iron to phosphorus was 2. Ferrous iron was almost completely removed at pH 8. A cost analysis is given for the maximum distance for which it is economical to pump AMD for combined treatment with wastewater.

364. Rabe, R. W., R. C. Wissmer, and R. F. Minter.
1973. Plankton populations and some effects of mine drainage on primary productivity of the Coeur d'Alene River, Delta, and Lake. 28 p. Water Resour. Res. Inst., Univ. Idaho, Moscow. [Available NTIS as PB-216 811/0.]

Variations in primary production and physiochemical measurements in the Coeur d'Alene River and Lake in Idaho were examined. These bodies of water have received mine tailings and metallic sulfide minerals for the last 80 years. Metal concentrations of Md, Cd, Mg, Ca, Pb, Cu, Zn, Fe, Na, and K; water quality; and phytoplankton composition-density were determined. Additional sampling included unpolluted portions of Coeur d'Alene Lake and the unaffected St. Joe River.

Nannoplankton from Coeur d'Alene Lake were exposed to known concentrations of Cu^{2+}, Zn^{2+}, and dilutions of Coeur d'Alene River water under controlled light and temperature. Inhibitory effects of separate and interacting metals on carbon 14 uptake by algae were assessed with factorial bioassays and response surfaces.

365. Ross, L. W.
1973. Removal of heavy metals from mine drainage by precipitation. 71 p. Dep. Chem. Eng. and Metallurgy, Denver Univ., Colo. [Available NTIS as PB-228 584/9ST.]

Heavy metals in mine drainage waters of the Rocky Mountains can be removed by a two-stage process consisting of neutralization followed by sulfide treatment. The first stage removes ferric and aluminum hydroxides, and the second (sulfide) stage precipitates the heavy metals that are most objectionable as pollutants, and that are of possible interest for economic recovery. The two-stage process has been demonstrated in the laboratory and in a field experiment.

366. Svanks, K., and K. S. Shumate.
1973. Factors controlling sludge density during acid mine drainage neutralization. 156 p. Water Resour. Cent., Ohio State Univ., Columbus. [Available NTIS as PB-226 615/3.]

Laboratory scale experiments were employed to investigate the feasibility of coal mine drainage neutralization treatment with the formation of magnetite and other high density/low volume sludges. Where applicable, the effects of bacterial catalysis on ferrous iron oxidation were incorporated into the investigations. Major process types studied included magnetite formation and high density sludge from lime treatment of acid mine drainage. Both acidic iron solutions and synthetic acid mine drainage were studied, primarily in batch process reaction systems, both with and without sludge recycle. Emphasis was placed on development of a basic understanding of the results observed, and interpretations drawn heavily from both experimental results and an incisive literature review.

367. Wilmoth, R. C.
1974. Limestone and limestone-lime neutralization of acid mine drainage. 101 p. Crown Mine Drainage Control Field Site, Environ. Protect. Agency, Riversville, W.Va. [Available NTIS as PB-237 607/0ST.]

The critical parameters affecting neutralization of ferric-iron acid mine waters were characterized by the Environmental Protection Agency in comparative studies using hydrated lime, rock-dust limestone, and a combination of the two as neutralizing agents. The advantages and disadvantages of each of these neutralizing agents were noted. On the ferric-iron test water, combination limestone-lime treatment provided a better than 25 percent reduction in materials cost as compared to straight lime or limestone treatment. Significant reduction in sludge production was noted by the use of rock-dust limestone and by the use of combination treatment as compared to hydrated-lime treatment. Emphasis on optimizing limestone utilization efficiencies resulted in an increase from approximately 35 to 50 percent utilization. Studies using limestone that had been ground to pass a 400-mesh screen resulted in utilization efficiencies near 90 percent.

368. Wilmoth, R. C.
1978. Combination limestone-lime neutralization of ferrous iron acid mine drainage. 63 p. Industrial Environmental Research Lab., Cincinnati, Ohio. [Available NTIS as PB-280 169/4ST.]

Studies were conducted on ferrous-iron acid mine drainage (AMD) treatment by a two-step neutralization process in which rock-dust limestone was mixed with the influent AMD and the hydrated lime was added in a polishing reactor. This combination treatment process resulted in reagent consumption cost reductions as high as 30 percent as compared to single-stage lime treatment of the same AMD. Later data indicated that an equal cost reduction (compared to single-stage lime treatment) could be achieved by a two-stage hydrated lime process in which the AMD and recycled sludge were mixed in the first reaction vessel and hydrated lime was added in the second reactor. No cost advantage for the combination process over straight hydrated lime treatment seemed to exist in situations where sludge recycling was not employed.

369. Wilmoth, R. C., and R. B. Scott.
1970. Reverse osmosis treatment of concentrated ferrous iron acid mine drainage. 16 p. Norton Mine Drainage Filed Site, Fed. Water Qual. Admin., Norton, W.Va. [Available NTIS as PB-216 359.]

A 4,000 gal/day reverse osmosis unit was tested on a severely polluted ferrous iron acid mine discharge near Morgantown, W.Va. The water recovery rate was limited to 50 percent due to membrane fouling problems. The role of ferrous iron fouling could not be identified because of a predominance of calcium sulfate precipitation on the membranes. The feasibility of reverse osmosis treatment is doubtful for mine drainage having concentrations of acidity, iron, sulfate, and calcium as high as 5 000 mg/l, 2 300 mg/l, 10 000 mg/l and 525 mg/l, respectively, due to the membrane fouling problem, maximum recoveries of only 50 percent, and the nonpotable quality of the product water.

3. EFFECTS ON AQUATIC ECOLOGY AND BIOTA

370. Bell, D. M.
1977. Effects of a zinc mine groundwater effluent on a stream diatom community. Periphyton. Proc. Penn. Acad. Sci. 51(1):51-53.

371. Brown, B. E.
1976. Observations on the tolerance of the isopod *Aesellus meridianus* (Rac.) to copper and lead. Water Res. 10:555-559.

Aesellus meridianus from sites receiving mine-drainage in the Hayle and Gannel Rivers in Cornwall exhibited, in toxicity tests and growth rate experiments, particular tolerance to copper and lead. Isopods from the Hayle, a river high in concentrations of copper in both water and sediments and low lead concentrations, were tolerant to both copper and lead. Isopods from the Gannel, a river with moderately high concentrations of copper and exceptionally high concentrations of lead, were tolerant to lead only. Tolerance to lead was shown to persist in animals from the Gannel F_2 generation that had been cultured in the laboratory.

372. Cumming, K. B., and D. M. Hill.
1971. Stream faunal recovery after manganese strip mine reclamation. 41 p. Coop. Fish. Unit., Virginia Polytech. Inst., Blacksburg. [Available NTIS as PB-206 184.]

The results of the investigation suggest a number of conditions to be met for effective reclamation, particularly of manganese strip mines, and in general of any surface mining that tends to increase the degree of siltation and turbidity in receiving waters. Seasonal monitoring of certain chemical, physical, and biological parameters of streams draining manganese strip mine spoils in three stages of reclamation verified that the community structure of fish and benthic macroinvertebrates in these streams remains severely depressed until complete

reclamation of the spoils has been accomplished. Laboratory studies established the median tolerance limits of three native species of fishes to silt in suspension and to manganese ions. These studies suggest that the principal factor depressing the faunal communities in partially reclaimed and unreclaimed streams is the chronically high degree of turbidity and siltation.

373. Dills, G. G., and D. I. Rogers, Jr.
1972. Aquatic-biotic community structure as an indicator of pollution. 31 p. Geol. Surv. of Alabama Univ. [Available NTIS as PB-216 801/1.]

Generally aquatic systems exposed to environmental stress (pollution) have fewer species and less diversity than naturally occurring communities. In the present study physiochemical conditions and community structure of benthic macroinvertebrates were investigated in a drainage system polluted with acid mine drainage. A statistical interpretation was performed to show possible correlation between water parameters and species diversity. The applicability of using the macroinvertebrate community structure to evaluate stream conditions consequent to acid flow is discussed.

374. Gale, W. L., and others.
1974. The impact of lead mine and mill effluent on aquatic life. In Forty-Seventh Annual Meeting and Thirty-Fifth Annual Mining Symposium, Proc. [Duluth, Minn., Jan. 16-18.] p. 76-81. P. J. Fedkenheuer, ed. Am. Inst. Mining, Metallurgical, and Petroleum Eng., Minn. Sec., and Univ. Minn., Minneapolis, Min. Resour. Res. Cent. 150 p.

The rapid development of Missouri's New Lead Belt into the world's largest lead producing region has been accompanied by a number of local alterations in the Ozark stream environment. Research findings are presented as to the probable and potential causes of stream alteration by the effluent from lead-zinc mines and associated mills. Comparison of relatively unaffected or "nonpolluted" streams and those streams which consistently demonstrate marked alteration have been evaluated with a comparative study of the different industrial practices and various chemical and physical parameters employed in extractive metallurgy. Industrial techniques or procedures that are most likely responsible for environmental alteration are defined, along with suggestions for pollution control methods.

375. Gale, N. L., P. Marcellus, and G. Underwood.
1974. Life, liberty and the pursuit of lead: the impact of lead mining and milling activities on aquatic organisms. In Trace Contam. Conf. 2d Annu. Proc. [Pacific Grove, Calif., August.] p. 295-307.

Bound lead in field or laboratory specimens was removed by washing with ethylenediaminetetra-acetate (EDTA) in concentrations as low as 0.01 M at pH 7.5. The results of analyses of various consumer organisms have indicated no biomagnification of lead in the grazing food chains involving aquatic vegetation. Data in tabular and graphical form are appended.

376. Hawkes, C. L.
1979. Aquatic habitat of coal and bentonite clay strip mine ponds in the northern Great Plains. In Ecology and coal resource development, vol. 2. p. 609-614. Mohan K. Wali, ed. Pergamon Press, New York.

377. Justyn, J., and S. Lusk.
1976. Evaluation of natural radionuclide contamination of fishes in streams affected by uranium ore mining and milling. Zool. Listy 25(3):265-274.

378. Klose, P. N.
1978. Effects of a zinc mine effluent on the benthic macroinvertebrate fauna of Saucon Creek, Lehigh and Northhampton Counties, Pennsylvania. Ph.D. thesis. Lehigh Univ., Bethlehem, Penn. 214 p. [Diss. Abstr. Int. 39/03-B:1113.]

379. Lewis, M. A.
1977. Aquatic inhabitants of a mine waste stream in Arizona. USDA For. Serv. Res. Note RM-349, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

380. Lewis, M. A.
1977. Influence of an open-pit copper mine on the ecology of an upper Sonoran intermittent stream. Ph.D. thesis. Ariz. State Univ., Tempe. 122 p. [Diss. Abstr. Int. 38/03-B:1033.]

381. Lewis, M. A.
1978. Acute toxicity of copper, zinc, and manganese in single and mixed salt solutions to juvenile longfin dace, *Agrosia chrysogaster*. J. Fish. Biol. 13:695-700.

382. Lewis, M. A.
1979. Impact of copper-mining on the ecology of a desert intermittent stream in central Arizona: a summary. J. Ariz.-Nev. Acad. Sci. 14:22-30. [Abbreviated form of Ph.D. dissertation (Ariz. State Univ.) entitled, "Influence of an open-pit copper mine on the ecology of an upper Sonoran intermittent stream."]

383. Lewis, M. A., and S. Gerking.
1979. Summer primary productivity in an intermittent desert stream. Am. Midl. Nat. 102:172-174.

Estimate of primary productivity in a mine-polluted stream.

384. Lind, O. T., and R. S. Campbell.
1970. Community metabolism in acid and alkaline strip-mine lakes. Trans. Am. Fish. Soc. 99(3):577-582.

Community metabolism was measured over a 24-month period by a modified dial oxygen procedure in three Missouri strip-mine lakes, one acid and two formerly acid. Water pH ranged from 3.2 to 8.1. Biotic diversity was inversely related to acidity. Maximum daily values of gross photosynthesis were similar in the lakes (7.9, 7.6, and 6.5 g O_2/m^2/day, but the highest rates of annual gross volumetric photosynthesis (586 and 682 g O_2/m^3/yr) were found in the more nearly eutrophic alkaline lake. Community respiration values, which were reasonably similar in the lakes, were considerably lower than in ponds and Texas coastal bays of similar photic depth. Rates of community respiration closely paralleled gross photosynthesis so that the photosynthesis:respiration ratio of each lake fluctuated about unity. Community function in these acid and alkaline lakes, judged by miles of photosynthesis and respiration, compares favorably with community function in nonacid natural waters.

385. McMahon, B., P. McCart, A. Peltzner, and others.
1977. Toxicity of saline groundwater from Syncrude's Lease 17 to fish and benthic macroinvertebrates. Syncrude Canada Ltd., Environ. Res. Monogr. 1977-3, 99 p.

The mining of the tar sands that are included in the area to be developed by Syncrude Canada Ltd. will require the dewatering of the mine pits. This will involve the pumping of large volumes of saline groundwater. Present plans call for its eventual disposal through Ruth Lake, the Poplar River, and, finally, the Athabasca River. This study was designed to determine whether groundwater from the mine area is toxic to aquatic organisms and, if so, the concentrations at which this toxicity is expressed. A variety of species, including both fish and aquatic insects, was tested to determine the range of sensitivity among aquatic animals. The resultant data can, with some qualifications, be used to estimate the maximum safe concentrations of groundwater that can be added to natural waters with minimal risk of toxic effects.

386. Norton, L. R., and N. R. Chymko.
1978. Water quality and aquatic resources of the Beaver Creek diversion system, 1977. Syncrude Canada Ltd., Environ. Res. Mongr. 1978-3, 340 p.

Water quality and aquatic resources of the system that was formed when Beaver Creek was diverted away from the developed area were studied from March to November 1977. Two newly created water bodies were characterized.

387. Platts, W. S., and S. B. Martin.
1978. Hydrochemical influences on the fishing within the phosphate mining area of eastern Idaho. USDA For. Serv. Res. Note INT-246, 15 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

388. Sherk, J. A., Jr.
1969. Effects of low levels of phosphate mining effluent on periphyton in controlled artificial estuaries. Ph.D. diss. North Carolina State Univ., Raleigh. 89 p. [Diss. Abstr. Int. 30/11B:5123.]

389. Sigler, W. F., W. T. Helm, J. W. Angelovic, and others.
1966. The effects of uranium mill wastes on stream biota. Utah Agric. Exp. Stn. Bull. 462, 76 p. Logan, Utah.

390. Sykora, J. L., and others.
1975. Some observations on spawning of brook trout (*Salvelinus fontinalis* Mitchill) in lime neutralized iron hydroxide suspensions. Water Res. 9(4):451-458.

391. Van Meter, W. P.
1974. Heavy metal concentration in fish tissue of the upper Clark Fork River. 45 p. Water Resour. Res. Cent., Mont. State Univ., Bozeman. [Available NTIS as PB-237 429/6ST.]

Specimens of game and rough fish from the upper Clark Fork River basin of western Montana have been analyzed by atomic absorption spectroscopy for cadmium, copper, lead, mercury, and zinc. Both muscle and liver tissue were analyzed. Procedures for the analyses are described in detail, including a sealed Pyrex tube method for the wet digestion of fresh tissue samples. Parts of the Flint Creek drainage are contaminated with mercury. Muscle concentrations in trout ranged up to 1.9 p/m. The mercury results from silver ore processing in the 19th century by the pan amalgamation method. Elevated levels of cadmium were found in one stream, the Little Blackfoot River, but no apparent source can now be identified.

392. Zitko, V., and W. G. Carson.
1977. Seasonal and developmental variation in the lethality of zinc to juvenile Atlantic salmon (*Salmo salan*). Mining pollution. J. Fish Res. Board Can. 34(1):139-141.

393. Zitko, V., W. V. Carson, and W. G. Carson.
1975. Thallium: occurrence in the environment and toxicity to fish. Bull. Environ. Contam. Toxicol. 13(1):23-30.

Thallium is present in the effluents of the base-metal mining industry, and its acute toxicity to juvenile Atlantic salmon is approximately equal to that of copper. The usual treatment of waste water with alkali to remove heavy metals by precipitation has little effect on thallium. The limited use of thallium will not lead to a global contamination of the environment, but localized problems may exist or develop in the future, mainly as a result of mineral processing.

G. Tailings, Spoils, Slimes, and Wastes

Section G contains citations on surface mine spoils; overburden; waste dumps; slime ponds; and tailings ponds, dams, and piles. It includes citations of the chemistry and physical properties of the spoils, as well as tailings dam construction and methods of dewatering slimes.

394. Anderson, M. A., D. L. Sorensen, P. B. Porcella, and others.
1976. Establishment of microbial populations in sterile mine spoils and overburden. II. Amendments required for acid mineral-mine spoils. 48 p. Utah Water Res. Lab., Logan.

Using mine spoil from the Blackbird Mine, Cobalt (near Salmon), Idaho, various combinations of nitrogen, phosphorus, chelators, trace elements, potassium, manure, and salt leaching were studied with the bioassay by microscopal observation and by measurement of nitrogen fixation and accumulation, dehydrogenase activity, chlorophyll accumulation, and other chemical parameters. It was concluded that the limiting factors for microbial (algal) growth were (in order of importance): soil moisture, pH control, and phosphorus.

395. American Cyanamid Co.
1969. Building land with phosphate wastes. Mining Eng. (New York) 21(12):38-40.

Disposal of phosphatic clays presents a costly problem to phosphate industry in Polk County, Fla., since it amounts to $0.24/ton of product. American Cyanamid Co. developed a technique to dispose of about 50 percent of waste clays and to build usable land. This technique also provides the additional benefits of tailings disposal, increased water recovery, and one-third reduction in circulation and settling costs, and a substantial decrease in the number of dams required for settling areas.

396. Arizona Bureau of Mines.
1971. Use of mineral waste products. Fieldnotes (Ariz. Bur. Mines) 1(2):4.

397. Bates, R. C.
1977. Rock sealant restricts falling barometer effect. Mining Eng. (New York) 29(12):38-39.

This rebuttal to a previous article provides new insight into the use of sprayed sealants in uranium mines. The author rejects the idea that the value of rock sealant on radon control is destroyed by changes in barometric pressure, showing that this is not necessarily true. The analyses described demonstrate that radon contamination resulting from changing barometric pressures is reduced by a rock coating. The overall use of coatings depends on their costs and effectiveness as compared with other radon control measures.

398. Bendersky, D., and others.
1977. A study of waste generation, treatment and disposal in the metals mining industry. 407 p. Midwest Res. Inst. Kansas City, Mo. [Available NTIS as PB-261 052/5WN.]

399. Bolter, E., B. G. Wixson, D. L. Butherus, and others.
1974. Distribution of heavy metals in soils near an active lead smelter. Am. Inst. Mech. Eng., Minn. Sec., 47th Annu. Meet., and 35th Univ. Minn. Annu. Mining Symp., Proc. p. 73-76.

The development of the 'New Lead Belt' or Viburnum Trend in southeast Missouri during the last decade has changed a sparsely populated, nonindustrialized area into the largest lead-producing mining district in the world. The growing concern over the impact of such a development on the ecology of the area prompted several companies and government agencies to support an interdisciplinary research project by scientists and engineers of the University of Missouri, Rolla and Columbia campuses, to delineate the extent of pollution, to determine individual pollution sources, and to suggest methods for the reduction or elimination of such problems. This paper describes the accumulation of heavy metals in soils caused by mining and smelting activities.

400. Borrowman, S. R., and P. T. Brooks.
1976. Radium removal from uranium ores and mill tailings. 16 p. Paper presented at the Am. Inst. Mech. Eng. Annu. Meet. [Chicago, Ill., 1973.] [Available NTIS as PB-250 751/5ST.]

401. Bortz, S. A.
1976. Utilization of mining and milling wastes. In Proc., Fifth Mineral Waste Utilization Symp. [April 13-14, 1976.] 21 p. IIT Research Inst., Chicago, Ill. [Available NTIS as PB-267 715/1ST.]

This report presents a review of studies and investigations concerning materials, energy, and products recovered from solid wastes. The bulk of the information presented is a summary of the "Fifth Mineral Waste Utilization Symposium" that was organized and presented as the principal objective of this program. A total of 52 papers was presented. Contents: metal recovery; energy recovery from solid wastes; waste utilization in construction; conclusion.

402. Campbell, J. A., W. A. Berg, and R. D. Heil.
1974. Physical and chemical characteristics of overburden, spoils and soils. In Surface rehabilitation of land disturbances resulting from oil shale development, executive summary. p. 31-39. C. W. Cook, ed. Colo. State Univ., Fort Collins, Environ. Resour. Cent., Infor. Series 11, 56 p.

403. Cannon, R. C., R. S. Ribas, J. Nickerson, and others.
1976. Elimination of washer slimes from the production of phosphate chemicals. 137 p. Fla. State Dep. Environ. Regulation, Tallahassee. [Available NTIS as PB-250 364/7ST.]

The report gives results of laboratory studies to determine the feasibility of a new phosphoric acid process involving dry mining of the matrix, calcination, and digestion with phosphoric/sulfuric acid mixtures (five types of Florida phosphate matrices were used). Process steps included upgrading the matrix by dry methods, calcination in a static bed, and digestion comparable to commercial dehydrate processes. The matrix samples were upgraded by removing clay through selective grinding and air classification, and by separation of the sand fraction electrostatically. Typical clay removal values were 80-90 percent at a phosphate loss of 15-25 percent. Calcination produced an acceptable phosphoric acid from good quality matrix, but failed to reject metal impurities sufficiently to permit processing of poor-to-average matrix. Calcination eliminated the interference of clay in the digestion and filtration steps. Addition of mineralizers had only marginal effects on metal solubility.

404. Chacho, E.
1978. Snow and erosion in the phosphate mining area of Idaho. Annu. Rep. 1977-78. 110 p. Univ. Idaho, Moscow.

This report covers four major subject areas: (1) meteorology in the mining area, (2) erosion from mine dumps, (3) snow accumulation, distribution, and abaltion on a mine dump, and (4) the size and location of snowdrifts in the mining area. Each subject is discussed separately in the report and consists of summaries of data and a brief account of the analysis completed to date.

405. Clements, L. W., and others.
1975. Charcterization studies of Florida phosphate slimes. 8 p. U.S. Bur. Mines, Tuscaloosa Metallurgy Res. Lab., University, Ala.

406. Collins, R. J., and R. H. Miller.
1976. Availability of mining wastes and their potential for use as highway material, vol. I. Classification and technical and environmental analysis. 308 p. Valley Forge Labs., Inc., Devon, Penn. [Available NTIS as PB-266 170/0ST.]

Over 1.6 billion tons of mining and metallurgical wastes are produced each year. Although a small percentage of all this material is actually being used, a number of mining and metallurgical wastes have been successfully utilized as highway construction material. A number of other mineral wastes are potentially useful with some degree of processing. Materials most highly recommended for use in highway construction are gold gravel, steel slag, lead-zinc chat, phosphate slag, taconite tailings, copper slag, and waste rock from the mining of copper, fluorspar, gold, and iron ore.

407. Collins, R. J.
1976. Availability of mining wastes and their potential for use as highway material, vol. II. Location of mining and metallurgical wastes and mining industry trends. 141 p. Valley Forge Labs., Inc., Devon, Penn. [Available NTIS as PB-266 171/8ST.]

This study was performed to determine the availability of mining and metallurgical wastes and to assess their potential for use in highway construction. A large number of information sources were used to develop an inventory and classification system for these wastes. Information presented in volume II was obtained mainly from knowledgeable personnel in the mining industry and government agencies, supplemented by key reports and industry periodicals. Maps and tabulations of mineral wastes from 35 principal mining States are presented in this volume.

408. Clifton, J. R., P. W. Brown, and G. Frohndorff.
1977. Survey of uses of waste materials in construction in the United States. 64 p. Materials and Composites Sec., Natl. Bur. Standards, Washington, D.C. [Available NTIS as PB-270 854/3ST.]

This survey covers the sources, amounts, and disposal of major mining, industrial, and municipal wastes available in the 48 conterminous states of the United States along with their present and potential uses as construction materials. Wastes from mining, industrial, and municipal sources are treated separately and in that order, which is the order of decreasing amount of usable wastes available from each major classification. Wastes from mineral, metallic ore and coal mining operations are covered in section 2. Industrial wastes are treated in sections 3 to 5. Section 3 describes a variety of important wastes that have found few markets; byproducts from coal combustion are discussed in section 4; and section 5 covers slags, byproducts which are already extensively used as aggregates in construction but for which there may be higher value uses. Municipal wastes, including municipal refuse, incineration residue, glass, demolition waste, and sewage sludge, are the subject of section 6. Section 7 is directed toward some potential wastes that may be generated in substantial amounts by emerging technologies related to energy production and environmental protection. Obstacles to and incentives for the increased use of waste materials in construction are discussed in section 8.

409. Colorado State University.
1976. Research needs for mining and industrial solid waste disposal. 40 p. Colo. State Univ., Fort Collins. [Available NTIS as PB-269 247/3ST.]

Representatives of the geotechnical and environmental engineering professions, industry, and governmental agencies participated in a 2-day workshop to identify research needs in the area of mining and industrial solid waste disposal. This report, which was prepared by the participants during the workshop, identifies 19 areas of needed research. The most critical need is for establishment of a reliable source of data concerning the magnitude of the waste disposal problems. Other areas of needed research are properties of wastes, seepage, surface stabilization, tailing structures, field instrumentation, abandonment, materials handling, material placement, climatic conditions, spontaneous combustion, and new methods of disposal.

410. Culbertson, W. J., Jr., T. D. Nevens, and R. D. Hollingshead.
1970. Disposal of oil shale ash. Colo. Sch. Mines Quar. 64(4):89-132.

411. DePuit, E. G., J. G. Coenenberg, and K. J. Dollhopf.
1979. Salt translocation in saline-sodic mine spoils. Interim report: effects of field irrigation and amendment treatments on vegetation establishment in 1978. 33 p. Mont. Agric. Exp. Stn., Mont. State Univ., Bozeman.

Supplemental irrigation significantly promoted seeded perennial grass establishment, productivity, and canopy cover during the first growing season. Species most stimulated by irrigation were slender wheatgrass, smooth bromegrass, pubescent wheatgrass, and blue grama, although nearly all other major established grasses were benefited to some extent. Invading weeds were consistently, although not significantly, reduced in irrigated as opposed to nonirrigated plots. Plant community diversity was higher in irrigated than in nonirrigated plots. These short-term, initial results suggest a great potential for use of irrigation in terms of enhancement of vegetation establishment. Further research is necessary, however, on long-term effects of irrigation and irrigation cessation on vegetational trends. First-year vegetation data showed no significant superiority of the four amendments over the nonamended control nor any significant differences among amendment treatments. It is believed that valid differences among amendment treatments and control plots may develop in the future, by which time sufficient plant root penetration and/or sodium upward or downward migration may cause changes in vegetation development.

412. Douglas, R. L., and J. M. Hans, Jr.
1975. Gamma radiation surveys at inactive uranium mill sites. Off. Radiation Prog., Rep. No. ORP/LV-75-5, 97 p. Las Vegas, Nev.

413. Dreesen, D. R.
1978. Uranium mill tailings - environmental implications. Los Alamos Sci. Lab. Mini-Review, LASL 77-37, 4 p.

414. Duncan, D. L., and G. G. Eadie.
1974. Environmental surveys of the uranium mill tailings pile and surrounding areas, Salt Lake City, Utah. 131 p. Uranium Mining and Mill Tailings Proj., Off. Radiation Prog., Las Vegas, Nev. [Available NTIS as PB-241 247/6ST.]

Environmental surveys have been conducted for the Utah State Division of Health's Occupational and Radiological Health Section at the former Vitro Corporation uranium mill and in the Salt Lake City, Utah, area. The surveys included measurement of external gamma radiation and airborne radioactivity. The results of the surveys indicated that: the external gamma radiation levels on the tailings area exceed recommended exposure limits; ambient levels of radon over the pile and in structures built immediately adjacent to the tailings pile are above the currently recommended concentration; tailings material has been removed from the Vitro site by persons and used around dwellings and businesses; and tailings material has become windborne and deposited against dwellings and structures in the vicinity.

415. Engineering and Mining Journal.
1971. Chemical treatment of waste tailings puts an end to dust storms. Eng. and Mining J. 172(4):104-105.

416. Engineering and Mining Journal.
1978. Revolutionary thickener design tackles heavy flow of zinc mine tailings. Eng. and Mining J. 179(4):78-79.

417. Farmer, E. E., and B. Z. Richardson.
1976. Hydrologic and soil properties of coal mine overburden piles in southeastern Montana. In Proc. of the Natl. Coal Assoc./Bituminous Coal Res. Coal Conf. and Expo III [Oct. 1976, Louisville, Ky.]. p. 120-130.

This paper reports the results of research conducted in 1973 and 1974 on the infiltration and erosion rates of bare overburden piles and examines the influence of several soil variables on these hydrologic characteristics. In spite of their relatively short existence, overburden piles are potential sources of water quality degradation, greatly accelerated erosion, and greatly increased surface water runoff. In the final analysis, the potential hydrologic problems associated with overburden piles are subject, almost totally, to the control of the mine operator.

418. Ford, Bacon and Davis Utah, Inc.
1977. Phase II, Title I engineering assessment of inactive uranium mill tailings, Falls City site, Falls City, Texas. 168 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-16.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium mill tailings at Falls City, Tex. Services included taking soil samples, the performance of radiometric measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions. Radon gas release from the 2.5 million tons of tailings at the Falls City site constitutes the most significant environmental impact. Windblown tailings, external gamma radiation, and localized contamination of surface waters are other environmental effects. The two alternative remedial action options presented include on-site and off-site cleanup, fencing, and hydrological monitoring, and, in addition, stabilization of pile 2 with 2 ft of cover material. The costs are $1.84 million for option I and $2.45 million for option II.

419. Ford, Bacon and Davis Utah, Inc.
1977. Phase II, Title I engineering assessment of inactive uranium mill tailings, Green River site, Green River, Utah. 153 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-14.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium mill tailings at the Green River site, Utah. Services included the preparation of topographic maps, the performance of core drillings and radiometric measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions. Radon gas release from the 123 thousand tons of tailings at the Green River site constitutes the most significant environmental impact, although windblown tailings and external gamma radiation are also factors. The three alternative actions presented are dike stabilization, fencing, on- and off-site decontamination and maintenance (option I); improvements in the stabilization cover and diking plus cleanup of the site and Browns Wash, and realignment of Browns Wash (option II); and addition of stabilization cover to a total of 2 ft, realignment of Browns Wash and placement of additional riprap, on-site cleanup and drainage improvements (option III). All options include remedial action at off-site structures. Cost estimates for the three options range from $700,000 to $926,000.

420. Ford, Bacon and Davis Utah, Inc.
1977. Engineering assessment of inactive uranium mill tailings, Gunnison site, Gunnison, Colo., Phase II, Title I. 237 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-12.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium mill tailings at Gunnison, Colo. Services included the preparation of topographic measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions. Radon gas release from the 0.5 million tons of tailings at the Gunnison site constitutes the most significant environmental impact, although windblown tailings and external gamma radiation are also factors. The nine alternative actions presented range from millsite decontamination (option I), to adding various depths of stabilization cover material (options II and III), to removal of the tailings to long-term storage sites and decontamination of the present site (options IV through IX). Cost estimates for the nine options range from $480,000 to $5,890,000. Reprocessing the tailings for uranium does not appear to be economically attractive at present.

421. Ford, Bacon and Davis Utah, Inc.
1977. Engineering assessment of inactive uranium mill tailings, Maybell site, Maybell, Colo., Phase II, Title I. 255 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-11.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium mill tailings at Maybell, Colo. The services included the preparation of topographic maps, the performance of core drillings sufficient to determine areas and volumes of tailings and radiometric measurements to determine radium-contaminated materials, the evaluation of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions. Radon gas release from the 2.6 million tons of tailings at the Maybell site constitutes the most significant environmental impact, although windblown tailings and external gamma radiation are also factors. The three alternative actions presented range from fencing and maintenance (option I), to placing the tailings in an open-pit mine and adding 2 ft of stabilization cover material (option III). Cost estimates for the three options range from $250,000 to $4,520,000. Reprocessing the tailings for uranium does not appear to be economically attractive at present.

422. Ford, Bacon and Davis Utah, Inc.
1977. Phase II, Title I engineering assessment of inactive uranium mill tailings, Mexican Hat site, Mexican Hat, Utah. 167 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-3.]

An engineering assessment of the problems resulting from the existence of radioactive uranium mill tailings at the Mexican Hat mill site in Utah is presented. Topographic maps, data on core drillings and radiometric measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting radiation exposures of individuals residing nearby, the investigation of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions are presented. Radon gas release from the 2.2 million tons of tailings on the site constitutes the most significant environmental impact. The six alternative actions presented are directed towards restricting access to the site, returning the windblown tailings to the piles and stabilizing the piles with cover material, and consolidating the two piles into one pile and stabilizing with cover material. Fencing around the site or the tailings and the decontamination of mill buildings is included in all options. Costs of the options range from $370,000 to $4,390,000.

423. Ford, Bacon and Davis Utah, Inc.
1977. Phase II, Title I engineering assessment of inactive uranium mill tailings, Monument Valley site, Monument Valley, Ariz. 172 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-4.]

An engineering assessment was made of the problems resulting from the existence of radioactive uranium mill tailings at the Monument Valley mill site in Arizona. The services included the preparation of topographic maps, the performance of core drillings and radiometric measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting radiation exposures of individuals residing nearby, the investigation of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions. Radon gas release from the tailings on the site constitutes the most significant environmental impact, although windblown tailings and external gamma radiation are also factors. The sparse population and relatively low radiation levels yield minimal immediate environmental impact; hence, the two alternative actions presented are directed toward restricting access to the site and returning the windblown tailings to the pile and stabilizing the pile. Both options include remedial action costs for off-site locations where tailings have been placed. Cost estimates for the two options are $585,000 and $1,165,000.

424. Ford, Bacon and Davis Utah, Inc.
1977. Engineering assessment of inactive uranium mill tailings, new and old Rifle sites, Rifle, Colorado, Phase II, Title I. 234 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-10.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium mill tailings at Rifle, Colorado. The services included the preparation of topographic maps, the performance of core drillings and radiometric measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions. Radon gas release from the 3.1 million tons of tailings at the two Rifle sites constitutes the most significant environmental impact. Windblown tailings, external gamma radiation, and localized contamination of surface waters are other environmental effects. The 15 alternative remedial action options presented range from mill-site decontamination and off-site remedial action (options I and IV), to adding various depths of stabilization cover material (options II, V, VI, and VII), to removal of the tailings to long-term storage sites and decontamination of the present sites (options III and VIII through XV). Cost estimates for the first 14 options range from $224,000 to $20,300,000. Option XV, estimated at $32,200,000, includes the cost for moving both Rifle tailings piles and the Grand Junction tailings pile to DeBeque for long-term storage and site decontamination after removal of the piles. Reprocessing of the tailings for uranium appears not to be economically attractive at present.

425. Ford, Bacon and Davis Utah, Inc.
1977. Phase II, Title I engineering assessment of inactive uranium mill tailings, Phillips/United Nuclear site, Ambrosia Lake, N.Mex. 151 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-13.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium mill tailings at the Phillips/United Nuclear site at Ambrosia Lake, N.Mex. Services included the preparation of topographic maps, the performance of core drillings sufficient to determine areas and volumes of tailings, and radiometric measurements to determine radiumcontaminated materials, the evaluation of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the evaluation and cost of alternative corrective actions. Radon gas release from the 2.6 million tons of tailings at the Phillips/United Nuclear site constitutes the most significant environmental impact, although windblown tailings and external gamma radiation are also factors. The estimated radiological health effects to the general population are considered to be minimal. The two alternative actions presented are: dike stabilization, fencing, and maintenance; and adding 2 ft of stabilization cover material. Both options include remedial action at off-site structures and on-site decontamination around the tailings pile. Cost estimates for the two options are $920,000 and $2,230,000, respectively.

426. Ford, Bacon and Davis Utah, Inc.
1977. Engineering assessment of inactive uranium mill tailings, Spook Site, Converse County, Wyo., Phase II, Title I. 142 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-15.]

An engineering assessment of the problems resulting from the existence of radioactive uranium mill tailings was performed at the Spook Site, Converse County, Wyo. Data are presented from soil, water, and other sample analyses, radiometric measurements to determine areas with radium-contaminated materials, the evaluation of resulting radiation exposures of individual and nearby populations, the investigation of site geology, hydrology, and meteorology, and the evaluation and cost of alternative corrective actions. Radon gas release from the 187,000 tons of tailings at the Spook Site constitutes the main environmental impact, which is negligible. The two alternative actions presented are better fencing of the site in its present state and placing tailings and contaminated on-site materials and soil in the open-pit mine and covering the resulting pile with 2 ft of overburden material. The cost estimates for the options are $82,000 and $142,000, respectively. Reprocessing the tailings for uranium at a nearby operating uranium mill is worthy of economic consideration at this time.

427. Ford, Bacon and Davis Utah, Inc.
1977. Summary of the Phase II, Title I engineering assessment of inactive uranium mill tailings, Tuba City site, Tuba City, Ariz. 51 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-5S.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium mill tailings at the Tuba City mill site in Arizona. Services include the preparation of topographic maps, the performance of core drillings and radiometric measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting radiation exposures of individuals residing nearby, the investigation of site hydrology and meteorology, and the evaluation and cost of alternative corrective actions. Radon gas release from the tailings on the site constitutes the most significant environmental impact to the inhabited area near the site.

428. Ford, Bacon and Davis Utah, Inc.
1977. Phase II, Title I engineering assessment of radioactive sands and residues, Lowman site, Lowman, Idaho. 133 p. Ford, Bacon and Davis Utah, Inc., Salt Lake City. [Available NTIS as GJT-17.]

An engineering assessment was performed of the problems resulting from the existence of radioactive uranium sand residues at the Lowman, Idaho, site. Services included the preparation of topographic maps, the performance of core drillings and radiometric measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting investigations of site hydrology and meteorology, and the evaluation and cost of alternative corrective actions. Radon gas release from the 90,000 tons of sand residues at the Lowman site constitutes the most significant environmental impact, although external gamma radiation is also a factor. The two alternative actions presented are dike construction, fencing, and maintenance (option I); and consolidation of the piles, addition of a 2-ft-thick stabilization cover, and on-site cleanup (option II). Both options include remedial action at off-site structures. Cost estimates for the two options are $393,000 and $590,000.

429. Franklin, J. C., T. O. Meyer, and R. C. Bates.
1977. Barriers for radon in uranium mines. 29 p. Spokane Mining Res. Center, Bur. Mines, Spokane, Wash. [Available NTIS as PB-277 331/5ST.]

Water-based epoxy sealants were examined during a 2-year period to determine their effectiveness as barriers to radon release in uranium mines. Radon emanation rates from uranium ore samples were monitored for extended periods in the laboratory before and after sealant application. Reduction of radon flux due to the coating of lab samples was approximately 80 percent. Test chambers in a dormant uranium mine were monitored to determine both short- and long-term barrier effectiveness. These field studies of the sealants indicated reductions greater than 50 percent relatively soon after application and nearly 75 percent more than 1 year later. An unexpected complication to early monitoring in the form of a large radon emanation increase, believed due to added moisture, is discussed.

430. General Accounting Office.
1978. The uranium mill tailings cleanup: Federal leadership at last. 60 p. Energy and Minerals Div., General Accounting Off., Washington, D.C. [Available NTIS as PB-283 064/4ST.]

The Department of Energy has proposed legislation that would allow it to enter into cooperative agreements with various States to clean up residual radioactive materials--commonly called uranium mill tailings--at 22 inactive uranium mills. About 25 million tons of mill tailings have accumulated at these sites since the 1940's. GAO analyzed the need for, and adequacy of, the proposed legislation and recommends that the cleanup program be endorsed. While the Federal Government has no apparent legal responsibility for such a cleanup, it does have a moral responsibility since the mills primarily produced uranium for Federal programs. Further, it is the only organization able to undertake such a cleanup program on a comprehensive basis. GAO also suggests several areas where the proposed legislation could be strengthened.

431. Girucky, F. E.
1972. New tailing dam construction at White Pine. In Tailings disposal today [First Int. Symp., Tucson, Ariz., Oct. 31-Nov. 3, Proc.]. p. 743-761. C. L. Aplin and G. O. Argall, eds. 860 p. Miller Freeman Publishers, Inc., San Francisco, Calif.

432. Goldsmith, W. A., F. F. Haywood, and R. W. Leggett.
1978. Transport of radon which diffuses from uranium mill tailings (summary paper). Int. Symp. on the Natural Radiation Environment III [Houston, Tex., Apr. 23-28, 1978]. p. 242-245.

433. Hagstrom, G. R., J. L. Stroehlein, and J. Ryan.
1976. Sulphuric acid + mining residue = promising iron fertilizer material. J. Sulphur Inst. 12(2):12-15.

434. Harvey, S., and T. Weaver.
1978. The annual cycle of soil-water availability on coal spoil, southeastern Montana. Proc. Mont. Acad. Sci. 38:85-87.

435. Hasebe, S., H. Sato, I. Matsuoka, and others.
1975. Slime treatment by flotation process in limestone mine. Technol. Rep. Iwate Univ. 10:35-44.

In a limestone mine, a large amount of slime is washed off in order to remove impurities such as clay minerals. A fine sized calcite is consequently wasted, and freight for carrying the slime to reclaim land is expensive. The separation of calcite from the slime by the flotation process, using sodium oleate as a collector, is investigated. A satisfactory flotation of calcite from the slime requires great amounts of sodium oleate, because sodium oleate is consumed by clay minerals. But, the amounts of sodium oleate required are reduced to half by adding suitable amounts of sodium silicate. After rougher and cleaner flotation, the concentrate containing more than 97 percent calcite is obtained with 70 percent recovery; thereby the amount of slime to be reclaimed is reduced to 40 percent.

436. Havens, R., and K. C. Dean.
1969. Chemical stabilization of the uranium tailings at Tuba City, Arizona. U.S. Bur. Mines Rep. of Investigations 7288, 12 p. Washington, D.C.

437. Heley, W.
1974. Processed shale disposal for a commercial oil shale operation. Mining Congr. J. 26(5):25-29.

438. Hersman, L. E.
1977. Microbial activity in strip mine spoils. Ph.D. diss. Mont. State Univ., Bozeman. 86 p.

439. International Energy Agency.
1976. Management of wastes from the mining and milling of uranium and thorium ores. Int. Energy Agency Safety Serv. 44:57.

440. Jackson, G., and S. Ware.
1977. The feasiblity of utilizing solid wastes for building materials. Executive summary. 96 p. Ebon Research Systems, Silver Springs, Md. [Available NTIS as PB-271 007/7ST.] .

This report focuses on two phases of a suggested four-phase study to evaluate the technological and commercial possibilities of waste-derived composites. The first phase involved a joint and comprehensive literature search to identify wastes with potential as building materials. Limited laboratory studies were conducted on composite materials produced from the more promising wastes investigated. A composite material was defined as a product containing a filler, a reinforcement, and a matrix. Various characteristics were considered desirable for the filler, the reinforcement, and the matrix. The wastes identified through the literature search were evaluated against these desirable properties. A listing of the evaluative criteria and the rating system used is presented. Filler materials reviewed included fly ash, crushed glass, phosphate slimes, silicate waste, shredded refuse, waste plastic, wood bark, rice hulls, taconite, red mud, coal waste, foundry ash, and sawdust. Reinforcement materials reviewed included

carbonized lignin, bagasse, wheat straw, bark, kenaf, bamboo, wood chips, cotton waste, and glass roving. Sewage sludge, sawdust, rice hulls, plastic scrap, and waste glass also received attention as reinforcements.

441. Jennett, J. C., and G. B. Wixson.
1972. Problems in lead mining waste control. Water Pollution Contr. Fed. J. 44(11):2103-2110.

442. Jeppson, R. W., R. W. Hill, and C. E. Israelsen.
1974. Slope stability of overburden spoil dumps from surface phosphate mines in southeastern Idaho. 69 p. Water Res. Lab., Utah State Univ., Logan.

443. Kenahan, C. B., R. S. Kaplan, J. Dunham, and others.
1973. Bureau of Mines research program on recycling and disposal of mineral-, metal-, and energy-based wastes. 60 p. U.S. Bur. Mines, Washington, D.C. [Available NTIS as PB-227 476/9.]

A summary of Bureau of Mines research on utilization and disposal of solid wastes is presented, accompanied by an extensive bibliography of related publications. The Bureau's Solid Waste and Materials Recycling Program is directed toward four main areas of research, development, and demonstrations: (1) extraction of mineral, metal, and energy values from urban refuse; (2) upgrading and recycling of automotive and related ferrous and nonferrous scrap; (3) utilization and stabilization of mine, mill, and smelter wastes; and (4) recovery and reuse of values from industrial waste products.

444. Kessick, M. A.
1978. Clay slimes from the extraction of Alberta oil sands, Florida phosphate matrix and other mined deposits. Can. Inst. Mining and Metall. Bull. 71(790):80-88.

445. Knopp, C.
1978. Infiltration erosion on phosphate mine overburden spoils. Master's thesis. Utah State Univ., Logan. 65 p.

This study was to determine if the sedimentary strata exhumed as phosphate strip mine overburden, and subsequently used as surface fill for waste dumps, exhibited different infiltration and erosion rates. Three different soils, as delineated by color, were present. Based upon analysis of variance tests, the infiltration and erosion rates for the three soils were different. Modulus of ruptures accounted for 56 percent of the variability in soil erosion, and provided an easy and effective means of correlating different sedimentary strata as to their relative erodibilities.

446. Lamont, W. E., and others.
1975. Characterization studies of Florida phosphate slimes. U.S. Bur. Mines, Rep. of Investigations 8089, 28 p. Washington, D.C.

447. Levins, D. M., R. K. Ryand, and K. R. Strong.
1978. Leaching of radium from uranium tailings. In Proc. Seminar on Management, Stabilization and Environmental Impact of Uranium Mill Tailings [Albuquerque, N.Mex., July 24-28, 1978]. p. 271-287. Organization for Econ. Coop. and Develop., Nuclear Energy Agency, Albuquerque, N.Mex., and Paris, France.

448. Ludeke, K. L.
1973. Soil properties of materials in copper mine tailing dikes. Mining Congr. J. 59(8):30-36.

449. Lush, D., J. Brown, J. R. Fletcher, and others.
1978. An assessment of the long-term interaction of uranium tailings with the natural environment. In Proc., Seminar on Management, Stabilization and Environmental Impact of Uranium Mill Tailings [Albuquerque, N.Mex., July 24-28, 1978]. p. 373-398. Organization for Econ. Coop. and Develop., Nuclear Energy Agency, Albuquerque, N.Mex., and Paris, France.

450. MacBeth, P. J., C. M. Jensen, V. C. Rogers, and others.
1978. Laboratory research on tailings stabilization methods and their effectiveness in radiation containment. U.S. Dep. Energy, Grand Junction, Colo., Rep. GJT-21, 117 p.

451. Mace, A. C., K. N. Brooks, J. P. Borovsky, and others.
1976. Feasibility of using iron ore overburden material as a media for disposal of secondary sewage effluent in northeastern Minnesota. 57 p. Water Resour. Res. Cent., Minn. Univ., Minneapolis. [Available NTIS as PB-281 307/9ST.]

The establishment and growth of municipalities and the extent of open-pit mining in the Mesabi Iron Range of northeastern Minnesota have created conflicts between economic development and environmental concerns. The discharge of secondary treated sewage effluent into streams and lakes by the numerous small Iron Range municipalities contributes to the eutrophication problem even though water quality standards may be achieved. The elimination of such nutrient pollution by means of tertiary treatment facilities would be, for the most part, economically prohibitive for these small communities. The disposal of treated sewage effluent on land, however, could provide a more feasible alternative. The purpose of this study was to investigate the feasibility of sprinkler irrigation of sewage effluent on iron-ore overburden deposits as a means of alleviating water quality problems. Specific objectives were to: (1) evaluate the efficiency of iron-ore overburden material to renovate secondary sewage effluent and thereby reduce the levels of nutrients entering receiving waters, and (2) evaluate amelioration characteristics of secondary sewage effluent to increase the establishment of grass, wildlife forage, and forest species on overburden sites.

452. Martin, J. B., and H. J. Miller.
1978. Generic environmental impact statement on U.S. uranium milling industry. In Proc., Seminar on Management, Stabilization and Environmental Impact of Uranium Mill Tailings [Albuquerque, N.Mex., July 24-28, 1978]. p. 453-469. Organization for Econ. Coop. and Develop., Nuclear Energy Agency, Albuquerque, N.Mex., and Paris, France.

453. May, J. T., H. H. Johnson, H. F. Perkins, and others.
1973. Some characteristics of spoil material from kaolin clay strip mining. In Ecology and reclamation of devastated land. [Int. Symp. on Ecol. and Reveg. of Drastically Disturbed Areas], vol. 1. p. 3-14. R. S. Hutnik and G. Davis, eds. Gordon & Breach, New York.

454. Mining Magazine.
1975. Florida phosphate mines test innovations in transport and tailings disposal. Mining Mag. (October):281-283.

455. Mink, L. L., R. E. Williams, and A. T. Wallace.
1972. Effect of early day mining operations on present day water quality. Ground Water 10(1):17-26.

456. Moffett, D.
1976. The disposal of solid wastes and liquid effluents from the milling of uranium ores. Can. Centre for Mineral and Energy Technology, Minerals Res. Prog., Mining Res. Lab., CANMET Rep. 76-19.

457. Moschopedis, S. E., and D. L. Mitchell.
1974. Sulfomethylated humic acid products as soil conditioners and fertilizers for the restoration of the Athbasca oil sand mining area. Can. For. Serv., Infor. Rep. NOR-X 116:152-161. North. For. Res. Cent., Edmonton, Alta.

458. Nebgen, J. W., J. G. Edwards, and D. F. Weatherman.
1976. Use of waste sulfate for remedial treatment of soils, vol. I. Discussion of results. 217 p. Midwest Res. Inst., Kansas City, Mo. [Available NTIS as PB-278 140/9ST.]

The effects of waste sulfate (phosphogypsum from fertilizer manufacture, fuel gas desulfurization solids, and neutralized acid mine drainage solids) on physical and strength properties of soils have been studied. Waste sulfate alone has little effect on soil strengths. However, if it is used in combination with lime, higher strengths can be achieved with waste sulfate/lime than can be obtained with equivalent lime treatment because of soil-sulfate-lime reactions. Fly ash can be used with waste sulfate/lime mixtures to improve strengths further. Cement kiln dust has been shown to be an effective substitute for lime as a soil stabilizer. The report is presented in two volumes. Volume I, Discussion of Results, describes the experimental work and contains the interpretation of data and conclusions and recommendations.

459. Nuclear Regulatory Commission.
1977. Branch position - uranium mill tailings management, Fuel Processing and Fabrication Branch [May 13, 1977]. Nuclear Regulatory Commission, Washington, D.C.

460. Parekh, B. K., and W. M. Goldberger.
1976. An assessment of technology for possible utilization of Bayer Process muds. 155 p. Battelle Columbus Labs., Ohio. [Available NTIS as PB-266 678/2ST.]

The program comprised reviews of technical literature published from 1940 on subjects related to technology of processing bauxite, the dewatering and impoundment of the mud residues and their possible utilization. Mud samples were received from the domestic alumina plants for characterization experiments and dewatering studies at Battelle and at the laboratories of the Dow Chemical Company in Midland, Mich. It was concluded from the study that there is no possibility for utilization of the muds that could significantly affect the need for impoundment within the near term. Improved mud dewatering and methods of impoundment appear possible to develop, however, and a program of joint industry-government investigations of the possible beneficiation of the muds into a raw material supplement in iron making and the possible use of mud as an absorbent in pollution abatement processes are also recommended.

461. Pigott, P. G., E. G. Valdex, and K. C. Dean.
1971. Dry-pressed building bricks from copper mill tailings. U.S. Bur. Mines, Rep. of Investigations 7537, 13 p. Washington, D.C.

462. Rouston, R. C., and others.
1977. Developments of chemical reactions, stability and transport model of oil shale process wastes in soil. In Pacific Northwest Annual Report for 1976 to the ERDA Assistant Administrator for Environment and Safety. p. 2.9-2.11. B. E. Vaughan, ed.

463. Scarano, R. A., and J. J. Linehan.
1978. Current U.S. Nuclear Regulatory Commission licensing review process: uranium mill tailings management. In Proc., Seminar on Management, Stabilization and Environmental Impact of Uranium Mill Tailings [Albuquerque, N.Mex., July 24-28, 1978]. p. 407-427. Organization for Econ. Coop. and Develop., Nuclear Energy Agency, Albuquerque, N.Mex., and Paris, France.

464. Schmidtke, N. W., D. Averill, D. N. Bryant, and others.
1978. Removal of 226 Ra from tailings pond effluents and stabilization of uranium mine tailings-bench and pilot plant studies. In Proc., Seminar on Management, Stabilization and Environmental Impact of Uranium Mill Tailings [Albuquerque, N.Mex., July 24-28, 1978]. p. 299-317. Organization for Econ. Coop. and Develop., Nuclear Energy Agency, Albuquerque, N.Mex., and Paris, France.

465. Schuman, G. E, W. A. Berg, and J. F. Power.
1976. Management of mine wastes in the western United States. In Land application of waste materials. p. 180-194. Soil Conserv. Soc. Am., Ankeny, Iowa. 313 p.

466. Shetron, S. G., and R. Rittler.
1973. Evaporation of water from reclaimed copper stamp sands. Mich. Tech. Univ., L'anse, Res. Note 8, 5 p.

Potential water losses from porous, structureless, sandy copper stamp sands by evaporation averaged 0.41 inch per day in the surface 6 inches for June, July, and August. Greatest potential loss was found to be 0.78 inch per day and lowest loss was 0.04 inch per day. Incoming weekly solar radiation averaged 0.890 Langleys. Available water (1/3-15 bar) storage capacity of the stamp sands in the upper 6 inches amounts to 1.65 inches of water.

467. Sorensen, D. L., M. A. Anderson, W. A. Kneib, and others.
1975. Establishment of microbial populations in sterile mine spoils and overburden. I. Development of microbial bioassay procedures. 40 p. Water Res. Lab., Utah State Univ., Logan.

Chemical and microbial analyses of overburden and topsoiling material (forest subsoil) from the Blackbird Mine near Salmon, Idaho, showed that microbial biomass and diversity were minimal. Bioassay methods were developed to assess the means of changing conditions so that stable and diverse microbial communities typical of fertile, productive soils could be established. Results of laboratory studies showed that the limiting factors for soil algal growth were, in order of importance: water availability, pH, and phosphorus. Other nutrients and heavy metal immobilization by pH adjustments were altered sufficiently by the above three parameters to allow considerable microbial productivity. A simple and convenient short-term bioassay technique was developed for use on soil systems.

468. Sorensen, D. L., W. A. Kneib, and D. B. Procella.
1979. Determination of sulfide in pyritic soils and minerals with a sulfide ion electrode. Anal. Chem. 51:1870-1872.

By combining sulfide ion selective electrode methodology with a method which releases sulfide ion from mineral matrices, a method has been developed which allows analysis of sulfide-sulfur in rocks and minerals without concern for interferences common to gravimetric sulfate analysis. The method has demonstrated good precision and accuracy in samples ranging from more than 50 to less than 0.01 percent sulfide-sulfur (relative standard deviation, 13 percent). Reliable sensitivity seems to be limited to about 0.03 percent sulfide-sulfur in a 150 mg sample. Sulfate-sulfur is reduced to sulfide-sulfur in analysis, and must be removed from sulfate-containing samples to avoid interference.

469. Sorensen, D. L., W. A. Kneib, D. B. Porcella, and others.
1980. Determining the lime requirement for Blackbird Mine spoil. J. Environ. Qual. 9:162-166.

The production of acid from oxidation of pyritic inclusions in mineral mine overburden prevents the revegetation of the overburden. A total lime requirement must be determined and met in order to control existing acidity and to prevent reacidification as oxidation of pyritic materials in the overburden continues.

470. Spendlove, M. J.
1977. Bureau of Mines research on resource recovery. Reclamation, utilization, disposal, and stabilization. 112 p. U.S. Bur. Mines, College Park, Md. [Available NTIS as PB-272 921/8ST.]

This report reviews in annotated form the Bureau of Mines research and related studies in the fields of resource recovery, land restoration, reclamation and stabilization, and utilization and/or disposal of postconsumer goods and industrial wastes. Numerous typical examples of research are discussed in each sector of the U.S. materials supply--utilization--disposal system. Included are raw materials extraction, raw material beneficiation, bulk materials processing manufacturing, secondary materials, and postconsumer materials utilization and disposal. Discussions are supported with appropriate charts, tables, diagrams, and photographic illustrations. Each section includes extensive lists of other related references.

471. Stanczyk, M. H., I. L. Feld, and E. W. Collins.
1971. Dewatering Florida phosphate pebble rock slime by freezing techniques. 25 p. U.S. Bur. Mines, Washington, D.C. [Available NTIS as PB-200-702.]

Freezing to dewater typical Florida phosphate rock slime as demonstrated in laboratory tests appeared to have potential commerical use because of indicated moderate energy requirements, good compaction of dewatered solids, and effective recovery of usable water. After freezing, thawing, decanting, and filtering, batch freezing of gallon-size 13.7 percent solids slime samples yielded 42 percent solids products. Cationic amine, used as a process additive, yielded 46.8 percent solids product with significant filter area reduction. Semicontinuous eight-stage freezing tests also produced thickened slimes. Cooling and freezing 13.7 percent solids slime from 50° to -10°C required removal of 183 Btu per pound of slime; Carnot cycle calculations indicate that the theoretical minimum energy to transfer this heat was 27.8 Btu per pound. To produce 1 ton of 44 percent solids slime from 13.7 percent solids slime, the calculated theoretical energy required for cooling and freezing was 52.3 kilowatt-hours. During the research, heat capacity and heat of fusion data were determined for the slime at various percent solids.

472. Striffler, W. D., I. F. Wymore, and W. A. Berg.
1974. Chracteristics of spent shale which influence water quality, sedimentation and plant growth. In Surface rehabilitation of land disturbances resulting from oil shale development, executive summary. p. 40-47. C. W. Cook, ed. Colo. State Univ., Fort Collins, Environ. Resour. Cent., Infor. Series 11, 56 p.

473. Terichow, O., G. V. Sullivan, and E. K. Landis.
1975. Electrophoretic studies of a Florida phosphate slime. U.S. Bur. Mines, Rep. of Investigations 8028, 17 p. Washington, D.C.

Electrophoretic mobility measurements were made by the Bureau of Mines on samples of a Florida phosphate slime to determine the optimum conditions of coagulation and settling in an aluminum sulfate solution. Addition of anthracite to promote mutual coagulation demonstrated the practicability of heterocoagulation by reduction of the repulsive effect of double layers. By proper selection of the electrolyte and its concentration, the reduction of the double layers to a net zero point of charge causes the predominance of Van der Waals' forces of attraction leading to the coagulation and rapid settling of both particle systems, as is predicted by the Derjaguin-Landua-Verway-Overbeek theory of colloidal stability. Confirmation was found in the microfiltration tests where a modified Carman equation was applied to evaluate the specific filter bed resistance.

474. Toland, G. C.
1971. A case history: design of a gypsum tailing pond. Mining Eng. 23(12):57-58.

475. U.S. Bureau of Mines and ITT Research Institute.
1970. Proc., Second Mineral Waste Utilization Symp., held March 18-19, 1970, Chicago, Ill. 373 p.

Symposium focuses on current efforts to utilize a wide spectrum of waste materials, ranging from abandoned automobiles to steel mill slags, paper mill sludges, mining tailings, and municipal refuse. More than 40 papers and panel discussions were published and those of particular interest include: ash utilization techniques; a profile of the nonferrous secondary metals industry; mineral content of municipal refuse; high temperature incineration; and utilization of waste glass. Selected papers are indexed separately.

476. Wallace, A., and others.
1976. Use of waste pyrites from mine operations on highly calcareous soil. Commun. Soil Sci. and Plant Anal. 7(1):57-60.

477. Weston, R. F.
1971. Concept evaluation report, taconite tailings disposal, Reserve Mining Company, Silver Bay, Minnesota. 159 p. R. F. Weston, Inc., West Chester, Penn. [Available NTIS as PB-259 510/6ST.]

The Office of Water Programs of the Environmental Protection Agency retained Roy F. Weston to develop conceptual methods for treating and disposing of the taconite wastes and to conduct an independent evaluation of feasible wastewater treatment and disposal alternatives. The sections cover the following: the major issues developed by previous studies of tailings discharges to Lake Superior; technical review of previous proposals for treatment and disposal of taconite tailings; discussion of Roy F. Weston's process investigation and tailings reuse; concept design of various alternatives for tailings processing and disposal; and the economic and financial impact on Reserve Mining and on the State of Minnesota of implementation of various proposals for taconite tailings disposal.

478. Weston, R. F., and M. L. Woldman.
1971. Taconite tailings disposal, Reserve Mining Company, Silver Bay, Minnesota. 179 p. R. F. Weston, Inc., West Chester, Penn. [Available NTIS as PB 253 346/1ST.]

The overall objective of this assignment is to develop minimum cost solutions consistent with the conference guidelines for protecting the environment in general and for conformance to the Federally approved "Specific Standards of Quality and Purity for Lake Superior" (contained in WPC 15) in particular. The limits or ranges of the various contaminant substances specified in "Specific Standards of Quality and Purity for Lake Superior" are shown. It should be noted that the assignment essentially was a presentation of an impartial evaluation rather than development of specific conclusions and recommendations. The sections cover the following: the major issues developed by previous studies of tailings discharges to Lake Superior, technical review of previous proposals for treatment and disposal of taconite tailings, discussion of Roy F. Weston's process investigation and tailings reuse, concept design of various alternatives for tailings processing and disposal, and the economic and financial impact on Reserve Mining and on the State of Minnesota of implementation of various proposals for taconite tailings disposal.

479. Williams, R. E., C. D. Kealy, and L. L. Mink.
1973. Effects and prevention of leakage from mine tailings ponds. Soc. Mining Eng. Am. Inst. Mining, Metallurgical and Petroleum Eng., Trans. 254(3):212-216.

480. World Mining.
1975. Kaiser drains red mud to make land fill. World Mining 28(3):53.

481. Yang, D. C.
1977. Disposal of mineral wastes and recovery of water from oxidized taconite slime tailings. Inst. Min. Res., Mich. Tech. Univ., Houghton. 140 p. [Available NTIS as PB-267 714/4ST.]

The report describes research to evaluate the flocculation, settling, and disposal of slimes and tailings from the beneficiation of oxidized taconite and to determine the effects of recycled water on the beneficiation process. The flocculation-desliming process was affected by pH, amine concentration, and water hardness. There were no deleterious effects from recycling water.

H. Effects on Flora

Citations in section H deal primarily with the effects of surface mining on vegetation. Citations on plants used for revegetation are included in section M. See also "Flora" in the index.

482. Alloway, B. J., and B. E. Davies.
1971. Heavy metal content of plants growing on soils contaminated by lead mining. J. Agric. Sci. (London) 76(2):312-323.

483. Amaugo, G. O.
1973. Effects of four soil materials in copper mine tailing disposal berms of total fiber, total protein, and amino acid content in pasture forage from barley. Master's thesis. Univ. Ariz., Tucson. 31 p.

484. Antonovics, J.
1972. Population dynamics of the grass *Anthoxanthum odoratum* on a zinc mine. J. Ecol. 60(2):351-365.

485. Berg, W. A., and W. G. Vogel.
1968. Manganese toxicity of legumes seeded in Kentucky strip-mine spoils. USDA For. Serv. Res. Pap. NE-119, 12 p. Northeast For. Exp. Stn., Broomall, Penn.

The occurrence of manganese toxicity was studied on six legume species grown in 46 different acid strip-mine spoils from Kentucky. This toxicity was characterized by a distinct chlorosis on the leaf margins that was readily seen on young leaves of all the species except *Kobe lespedeza*. Soil pH was useful in predicting Mn toxicity on the legumes; water soluble Mn extracted from the spoils was not. Korean and bicolor lespedeza seedlings were susceptible to Mn toxicity on spoils with pH below the range of 5.0 to 5.5. *Sericea lespedeza* in the seedling stage was also susceptible below this pH range, but on some spoils it outgrew the early toxicity symptoms. *Kobe lespedeza*, birdsfoot trefoil, and black locust did not show Mn toxicity symptoms on most spoils with pH above 4.5.

486. Cox, R. M., D. A. Thruman, and M. Brett.
1976. Some properties of the soluble acid phosphates of roots of zinc-tolerant and non-tolerant clones of *Anthoxanthum odoratum* growing near zinc and lead mines in Wales. New Phytol. 77(3):547-552.

487. Crundwell, A.
1976. *Ditrichum plumbicola*, a new species from lead-mine waste. J. Bryol. 9(2):167-169.

488. Fuller, W. H., and K. Lanspa.
1975. Uptake of iron and copper by sorghum from mine tailings. J. Environ. Qual. 4(3):417-422.

489. Hemphill, D. D., and J. P. Pierce.
1974. Accumulation of lead and other heavy metals by vegetation in the vicinity of lead smelters and mines and mills in southeastern Missouri. In Trace contamination in the environment [Proc. of the Second NSF-RANN Conf.]. p. 324-332.

490. Ireland, M. P., and R. J. Wooton.
1976. Variation in the lead, zinc, and calcium content of *Dendrobaena rubida (Oligochaeta)* in a base metal mining area. Environ. Pollution 10(3):201-208.

491. Johnston, W. R., and J. Proctor.
1977. A comparative study of metal levels in plants from two contrasting lead-mine sites. Plant Soil 46(1):251-257.

492. Lefebvre, C.
1970. Self-fertility in maritime and zinc mine populations of *Armeria maritima* (Mill.) Wild. Evolution 24(3):571-577.

493. Rascio, N.
1977. Metal accumulation by some plants growing on zinc-mine deposits. Oikos 29(2):250-253.

494. Takijima, Y., and F. Katsumi.
1973. Cadmium contamination of soils and rice plants caused by zinc mining. Soil Sci. and Plant Nutrition 19(1):29-38.

495. Tunney, H., G. A. Fleming, A. N. O'Sullivan, and others.
1972. Effects of lead-mine concentrates on lead content of ryegrass and pasture herbage. Irish J. Agric. Res. 11(1):85-92.

496. Wong, M. H., and F. Y. Tam.
1977. Soil and vegetation contamination by iron-ore tailings. Environ. Pollution 14(4):241-254.

497. Zwinger, A. H., and B. E. Willard.
1972. Land above the trees: a guide to American alpine tundra. 489 p. Harper & Row, New York.

I. Effects on Fauna

Citations in section I deal with the effects of surface mining on fish, wildlife, and domestic animals. Citations include those that are baseline data and inventories and those that describe the actual impacts on animals and habitat.

498. Blum, J. R.
1975. Oil shale and wildlife: what's it all about? In Environmental Oil Shale Symposium [Oct. 9-10] Proc. p. 147-152. J. D. Gary, ed. Colo. Sch. Mines, Quarterly 70(4). 244 p.

499. Catchpole, C. K., and C. F. Tydeman.
1975. Gravel pits as new wetland habitats for the conservation of breeding bird communities. Biol. Conserv. 8(1):47-59.

500. Dollahite, J. W., L. D. Rowe, L. M. Cook, and others.
1972. Copper deficiency and molybdenosis intoxication associated with grazing near a uranium mine. Southwest Vet. 26(1):47-50.

501. Egan, D. A., and J. O'Cuill.
1970. Cumulative lead poisoning in horses in a mining area contaminated with galena. Vet. Rec. 86(25):736-738.

502. Frischknecht, N. C.
1978. Use of shrubs for mined land reclamation and wildlife habitat. Reprinted from Proc. of Workshop on Reclamation for Wildlife Habitat. 14 p. Ecology Consultants, Inc., Fort Collins, Colo. USDA For. Serv., Intermt. For. and Range Exp. Stn., Ogden, Utah.

503. Institute of Land Rehabilitation.
1978. Rehabilitation of western wildlife habitat: a review. 237 p. Western Energy and Land Use Team, Off. Biol. Serv., U.S. Fish and Wildlife Serv., Fort Collins, Colo. [Available NTIS as PB-289-049 or GPO as 024-010-00513-1.]

504. Kuck, L.
1978. Southeast Idaho big game studies: I) Status and distribution of moose, elk, and mule deer in southeastern Idaho; II) phosphate mining impacts on big game; III) minimizing mining impacts on big game. Idaho Dep. Fish and Game, Proj. W-160-R-5, 139 p.

505. Layne, J. N.
1977. Fish and wildlife inventory of the seven-county region included in the central Florida phosphate industry areawide environmental impact study, vol. III, appendices A-G. 141 p. Am. Mus. Nat. Hist., Archbold Biol. Stn., Lake Placid, Fla. [Available NTIS as PB-278 458/5GA.]

This report is concerned with the potential impacts of phosphate mining on the fish and wildlife resources of the seven-county area (Charlotte, DeSoto, Hardee, Hillsborough, Polk, Manatee, Sarasota) of central Florida, where the phosphate industry in the State is presently concentrated, and where future expansion will occur. The objectives were to compile available data on the fish and wildlife resources in the region, including information on their distribution, habitat, and population levels; assess the direct and indirect impacts of phosphate mining on fauna; and recommend methods of mining or reclamation to minimize adverse effects on fish and wildlife.

506. Layne, J. N., J. A. Stallcup, G. E. Woolfenden, and others.
1977. Fish and wildlife inventory of the seven county region included in the central Florida phosphate industry areawide environmental impact study, vol. I. 656 p. Am. Mus. Nat. Hist., Archbold Biol. Stn., Lake Placid, Fla. [Available NTIS as PB-278 456/9GA.]

This report is concerned with the potential impacts of phosphate mining on the fish and wildlife resources of the seven-county area (Charlotte, DeSoto, Hardee, Hillsborough, Polk, Manatee, Sarasota) of central Florida, where the phosphate industry in the State is presently concentrated, and where future expansion will occur. The objectives were to compile available data on the fish and wildlife resources in the region, including information on their distribution, habitat, and population levels; assess the direct and indirect impacts of phosphate mining on fauna; and recommend methods of mining reclamation to minimize adverse effects on fish and wildlife.

507. Layne, J. N., J. A. Stallcup, G. E. Woolfenden, and others.
1977. Fish and wildlife inventory of the seven-county region included in the central Florida phosphate industry areawide environmental impact study, vol. II. 640 p. Am. Mus. Nat. Hist., Archbold Biol. Stn., Lake Placid, Fla. [Available NTIS as PB-278 457/7ST.]

This report is concerned with the potential impacts of phosphate mining on the fish and wildlife resources of the seven-county area (Charlotte, DeSoto, Hardee, Hillsborough, Polk, Manatee, Sarasota) of central Florida, where the phosphate industry in the State is presently concentrated, and where future expansion will occur. The objectives were to compile available data on the fish and wildlife resources in the region, including information on their distribution, habitat, and population levels; assess the direct and indirect impacts of phosphate mining on fauna; and recommend methods of mining or reclamation to minimize adverse effects on fish and wildlife.

508. Lefebvre, C.
1976. Breeding system and population structure of *Armeria maritima* (Mill.) Willd. on a zinc-lead mine. New Phytol. 77(1):187-192.

509. National Fish and Wildlife Laboratory.
1978. Osceola National Forest phosphate extraction and processing. 427 p. Natl. Fish and Wildl. Lab., Gainesville, Fla. [Available NTIS as PB-283 444/8ST.]

The report discusses habitat requirements and status in the Osceola National Forest of all wildlife species listed as endangered, threatened, rare, special concern, or status undetermined by the U.S. Fish and Wildlife Service, the State of Florida, or the Florida Committee on Rare and Endangered Plants and Animals. Distribution maps for each species confirmed from the Osceola National Forest are provided and wildlife habitats are described and mapped. Predicted impacts are based on comparisons with an active phosphate mine located in nearby Hamilton County, Fla. The report includes suggested mitigation and reclamation measures for all listed species, except those on the Federal list. This latter group will be addressed by the Office of Endangered Species, U.S. Fish and Wildlife Service.

510. Rafaill, B. L., and W. G. Vogel.
1978. A guide for revegetating surface mined lands for wildlife in eastern Kentucky and West Virginia. U.S. Dep. Interior, Fish and Wildlife Serv., Biol. Serv. Prog. FWS/OBS-78/84, 84 p.

This guide is a handbook to aid land managers in revegetating surface mined land areas for wildlife. The vegetation section included suitable species; planting and seeding methods (equipment needed, seedbed preparation); spoil amendments; and planting patterns beneficial to wildlife. The wildlife section includes habitat requirements for selected species.

511. Roberts, R. D., M. S. Johnson, and M. Hutton.
1978. Lead contamination of small mammals from abandoned metalliferous mines. Environ. Pollution 15(1):61-69.

512. Rogers, G. E.
1974. Oil shale development will affect wildlife. Colo. Outdoors 23(6):1-4.

513. Samuel, D. E., J. R. Stauffer, C. H. Hocutt, and others.
1978. Surface mining and fish/wildlife needs in the eastern United States [Proc. of a Symp., W.V. Univ.] U.S. Dep. Interior, Fish and Wildlife Serv., Biol. Serv. Prog. FWS/OBS-78/81, 386 p.

The symposium explored the relationships between mining and fish and wildlife. Sections include: lands (habitat) unsuitable for mining; planning to meet fish and wildlife needs; methods and techniques for impact assessment; mining effects on water quality and aquatic life; mining effects on terrestrial wildlife; reclamation techniques; wildlife utilization of mined lands; and opportunities for wildlife management on mined lands.

514. Shaid, T. A., and R. L. Linder.
1978. Nongame bird habitat associated with haul roads and surface mining for bentonite clay. S.Dak. Coop. Wildl. Res. Unit Quar. Rep. 15:10-12.

515. Spaulding, W. M., and R. D. Ogden.
1968. Effects of surface mining on the fish and wildlife resources of the United States. Bur. Sport Fish and Wildl. Resour. Publ. 68, 51 p.

Data obtained in a study of the effects of surface mining on fishing resources are compiled. About 2 million acres of fish and wildlife habitat are damaged by mining. This includes 13,000 miles of streams (135,970 acres), 281 lakes (102,630 acres), 168 reservoirs (41,516 acres) and 1,687,288 acres of land; 63 percent of the damage is east of the Mississippi. Problems are discussed and recommendations are made for their solutions.

516. Stewart, R. E., Jr.
1975. New energy research in the Fish and Wildlife Service. In Fort Union Coal Field Symp. Proc., vol. I, administrative section. p. 81-86. W. F. Clark, ed. East. Mont. Coll. Bookstore, Billings.

517. Watson, A. P., R. I. Van Hook, D. R. Jackson, and others.
1976. Impact of a lead mining-smelting complex on the forest-floor litter anthropod fauna in the New Lead Belt region of southeast Missouri. M.S. thesis. Univ. Kentucky, Lexington. 178 p. [Available NTIS as ORNL/NSF/EATC30.]

Studies of biological activity within the litter horizons of a watershed contaminated by emissions from a lead-ore processing complex focused on the litter-arthropod food chain as a means of detecting perturbations in a heavy-metal contaminated ecosystem. Both point sources (smelter stack emissions) and fugitive sources (ore-handling processes, yard dusts, and exposed concentrate piles) contributed to the Pb, Zn, Cu, and Cd levels in the study area. Arthropod trophic level density, biomass, and heavy metal content were determined by analysis of specimens removed from litter by Von Tullgren funnel extraction, taxonomically classified, and segregated into the trophic categories. Changes in litter decomposition were reflected in the dynamics of the litter arthropod community. Food-chain dilution of Pb, An, Cu, and Cd from litter to litter consumer was occurring, as indicated by the mean concentration factors. Accumulation of Pb by litter consumers was much less than that found for the other three heavy metals. In contrast, predatory arthropods on Crooked Creek Watershed either concentrated or equilibrated with respect to Pb, Zn, and Cd from their prey, as indicated by mean total predator concentration factors. A significant depression of the Ca, Mg, and K content litter occurred relative to the control within 0.8 km of the stack. Two mechanisms were postulated to explain this result: increased leaching of cations through the litter induced by a loss of cation exchange capacity, a decrease in pH, and a decrease in microbial immobilization of macronutrients; and a decreased uptake of macronutrients due to root damage produced by heavy-metal concentrations.

J. Effects on Human Health

Many of the citations in section J are related to industrial hygiene and the health of the miner. Also included are citations dealing with the impacts of certain commodity mining on the general health of the public.

518. Archer, V. E., D. Holaday, and others.
1973. Mortality of uranium miners in relation to radiation exposure, hard-rock mining, and cigarette smoking, 1950 through September, 1967. Handb. Exp. Pharmacol. 36:571-578.

519. Archer, V. E., J. D. Gillam, and L. A. James.
1975. Respiratory disease mortality among uranium miners as related to height, radiation, smoking and latent period. 30 p. Paper presented at 1975 Annu. Meet., Am. Public Health Assoc. [Available NTIS as HRP-000 6691/OST.]

A prospective mortality study using a life table method was done on 3,366 white underground uranium miners, and 1,231 surface workers. Observed deaths were found to exceed those expected from respiratory cancer, pneumoconiosis, and related diseases; and accidents related to work. Exposure-response relationships with radiation varied with cigarette smoking and with height of workers. Of four factors involved in both malignant and nonmalignant respiratory diseases (height, free silica, cigarette smoking, and alpha radiation), radiation was considered to be most important.

520. Australian Mineral Foundation Inc.
1972. Radiation controls in uranium mining. Health session. 118 p. Austr. Mineral Foundation, Inc., Adelaide. [Available NTIS as NP-19888.]

521. Clark, U.
1975. Natural radioactivity in the environment: the Florida phosphate study. In Seventh Annu. Natl. Conf. on Radiation Contr. 4 p. Food and Drug Admin., Rockville, Md.

Some topics discussed are: effects of phosphate mining on public health and the environment; concentrations of uranium and daughter products in phosphate ore; investigations of phosphate mining areas by the Florida Division of Health; development of an instrument for aerial survey of background radiation; evaluation of drinking water supplies; and use of waste products from mining operations for construction material.

522. Comar, C. L.
1968. Radiation exposure of uranium miners. 36 p. Natl. Acad. Sci.-Natl. Res. Counc., Washington, D.C. [Available NTIS as PB-180 247.]

Increasing attention has been given, within recent years, to observations that extended exposure in some uranium mines is associated with an increase in lung cancer. Upon approval by the Federal Radiation Council, its staff carried out a study on the radiation hazards associated with the underground mining of uranium ore.

523. Hans, J. M., Jr., and R. L. Douglas.
1975. Radiation survey of dwellings in Cane Valley, Arizona and Utah, for use of uranium mill tailings. 43 p. Off. Radiation Prog., Las Vegas, Nev. [Available NTIS as PB-245 869/3ST.]

A radiation survey was conducted in the Cane Valley area of Monument Valley, on the Navajo Reservation, to identify dwellings in which uranium mill tailings had been used and to assess the resulting radiation exposures. Sixteen of the 37 dwellings surveyed were found to have tailings and/or uranium ore used in their construction. Tailings were used in concrete floors, exterior stucco, mortar for stone footings, cement floor patchings, and inside as cement "plaster." Uranium ore was found in footings, walls, and in one fireplace. Other structures, not used as dwellings, were also identified as having tailings and ore use. Gamma ray exposure

rates were measured inside dwellings and structures identified as having tailings and/or ore used in their construction. Indoor radon progeny samples were collected in occupied dwellings where practical.

524. Holaday, D. A., D. E. Rushing, R. D. Coleman, and others.
1950. Control of radon and daughters in uranium mines and calculations on biologic effects. 93 p. Public Health Serv., Bur. State Serv., Washington, D.C. [Available NTIS as PB-216 579.]

A steadily mounting rate of uranium production has focused increasing attention on the health hazards associated with the mining of this strategic metal. Predominant among these hazards is exposure to radon, a dense gas emanating from the ore, together with the products which result from the radioactive decay of radon. To date, neither records of human exposure to radon daughter products nor data from animal experimentation have been available in sufficient quantity to permit a determination of a maximum permissible concentration for these elements. It has therefore been necessary to establish a working level that appears to be safe, yet not unnecessarily restrictive to industrial operations. Such a level, it is believed, has been established and recommended in the report.

525. Hollocher, T. C., and J. J. MacKenzie.
1975. Radiation hazards from the misuse of uranium mill tailings. In The nuclear fuel cycle--a survey of the public health, environmental and national security effects of nuclear power. p. 92-115. MIT Press, Cambridge, Mass.

The extraction of uranium from ore results in a sandlike material, called tailings, that still contains most of the original radium, and in some fluids and slimes that also contain radium. Prior to 1959 the disposal and handling of these materials caused the pollution of streams and water supplies by radium in the southwestern United States. Prior to 1966 uranium tailings were used as fill and for other construction purposes around buildings. Some 3,300 buildings have been discovered to be associated with tailings in and around Grand Junction (Mesa County), Colo.; some 5,000 buildings in the whole of Colorado; and perhaps 7,000-8,000 buildings altogether in the United States. The tailings emit alpha-rays and radon gas that expose persons indoors. In view of the situation described above and in anticipation of the milling of uranium ore that is soon to begin for the nuclear power industry, recommendations are made to alleviate the exposure.

526. Morgan, K. Z.
1978. Cancer and low level ionizing radiation. Bull. Atomic Sci. 34:30-41.

527. Saccomanno, G.
1975. Uranium miner lung cancer study. 9 p. Dep. Pathol., Saint Mary's Hospital, Grand Junction, Colo. [Available NTIS as COO-1826-32.]

The three projects supported by the Atomic Energy Commission consist of: collection of material from uranium miners known to have cancer of the lung into a tumor registry; manual of pulmonary cytology; regression study of sputum cytological findings in uranium miners who showed marked atypical squamous cell metaplasia and have quit smoking cigarettes, mining, or both. This study was active for the last 6 years and some interesting information is being accumulated. Approximately 60,000 sputum samples have been examined over the last 17 years in cases that showed normal cytology at the inception of study and subsequently developed carcinoma of the lung.

528. Saccomanno, G.
1976. Uranium miner lung cancer study. 8 p. Dep. Pathol., Saint Mary's Hospital, Grand Junction, Colo. [Available NTIS as COO-1826-35.]

This study on the rate of lung cancer development in uranium miners was initiated in 1957 by the U.S. Public Health Service and many facets of this project are reaching final objectives. Many new studies have developed in the course of this study and will continue. The projects supported by the Energy Research and Development Administration are of utmost importance and

consist of: collection of material from uranium miners known to have cancer of the lung into a tumor registry; manual on pulmonary cytology; regression study of sputum cytological findings in uranium miners who showed marked atypical squamous cell metaplasia and have quit smoking cigarettes, mining, or both; continuation of sputum collection and collection of lungs from deceased miners; and the development of instruments such as UV fiber-optic bronchoscopies for localization of carcinoma in situ of the lung. Approximately 75,000 sputum samples were examined over the last 19 years in cases that showed normal cytology at the inception of study and subsequently developed carcinoma of the lung and this has resulted in an accumulation of material that is worthy of study.

529. Swift, J., J. Hardin, and H. Calley.
1976. Potential radiological impact of airborne releases and direct gamma radiation to individuals living near inactive uranium mill tailings piles. 38 p. U.S. Environ. Protec. Agency, Washington, D.C.

530. Wagner, V., J. Andrlikova, V. Palek, and others.
1978. Levels of immunoglobulins (IGG IGA IGM) under effect of age and exposure to mining environment in uranium industry. Inst. Uranium Ind., Res. Dep., Public Health, Pribram, Czechoslovakia, Strahlentherapie 154(6):406-412.

531. Yamamoto, R., E. Yunoki, M. Yamakawa, and others.
1974. Studies on environmental contamination by uranium: 5. Uranium contents in daily diet and in human urine from several populations around a uranium mine in Okayama Prefecture. J. Radiation Res. 15(3):156-162.

K. Other Effects

Section K deals with other effects of surface mining on the environment and includes effects on archaeology, noise, and trace elements.

532. Jennett, J. C., A. J. Callier, and J. Foil.
1976. Trace metal and trace organic emissions to the environment by lead-zinc mining and milling operations. In Trace substances in environmental health [Proc., Univ. Missouri's 10th Annu. Conf.]. p. 251-264.

533. Jennett, J. C., B. G. Wixson, I. H. Lowsley, and others.
1977. Transport and distribution of lead from mining, milling, and smelting operations in a forest ecosystem. In Lead in the environment. p. 135-178. W. R. Boggess and B. G. Wixson, eds. National Science Foundation, Washington, D.C.

534. Laguros, J. G., J. F. Harp, and J. M. Robertson.
1978. Hydrogeotechnic considerations in surface mined lands. 12 p. Paper presented at Am. Geophys. Union, San Francisco, Calif., Dec. 1978.

The paper focuses on the hydrogeotechnic elements that should be considered in the development of an effective rehabilitation program.

535. Olson, A. P.
1975. Archaeological investigation and mitigation in the Three Corners area. In Environmental Oil Shale Symposium Proc. p. 89-93. Colo. Sch. Mines Quar. 70(4). 244 p.

536. Savich, M.
1974. Production, characteristics and abatement of noise from light and medium rock drills. Can. Inst. of Mining and Metall. Bull. 67(751):66-79.

Research was conducted to investigate the possibilities of noise abatement in light and medium rock drills. Detailed analysis of the theoretical and experimental solutions of light and medium rock drills showed that the relationships among force, thrust (penetration increase), and noise remained unresolved. The main characteristics of two medium rock drills--Type 2 rock drill and Type 3 muffled rock drill--were investigated and analyzed. For the comparative analysis of noise measurement, the Type 1 feed-leg drill was used. These investigations showed that rock drill noise is generated in the following manner: at frequencies below 125 Hz, by the impact between the piston and drill steel; at frequencies between 125 and 2000 Hz, by the exhaustion of air from the exhaust ports; and at frequencies above 2000 Hz, by the impact between the piston and drill steel, and between the drill steel and rock. Analysis showed that the system for noise abatement in rock drills can be further improved. In this research project, a proposition to achieve this end is given. To perform these measurements, the author gave his own variant of an anechoic chamber, constructed exclusively for the measurement of the noise of light and medium drills under different power thrusts.

537. Schreibeis, W. J., and H. H. Schrenk.
1961. Evaluation of dust and noise conditions at typical sand and gravel plants. 23 p. Natl. Sand and Gravel Assoc., Washington, D.C.

538. Weaver, T., and D. Klarich.
1973. Ecological effects of silver iodide in terrestrial ecosystems: a preliminary study. Mont. Agric. Exp. Stn., Bozeman, Res. Rep. 42, 19 p.

L. Reclamation Efforts and Revegetation

Citations included in section L are those that deal primarily with reclamation and revegetation effects, techniques and equipment used for reclamation, and resource and guideline books for reclamation.

539. Anderson, M. A.
1976. Microbial bioassay techniques for assessing acid mine spoil amendments for revegetation. M.S. thesis. Utah State Univ., Logan. 117 p.

540. Angster, G. L., and others.
1970. Reclamation. 43 p. N.C. Univ., Raleigh. [Available from Nello L. Teer Company, Durham, N.C.]

541. Bamberg, S. A.
1975. Approaches to large scale land reclamation in oil shale development. In Environmental Oil Shale Symposium Proc. p. 95-105. J. H. Gary, ed. Colo. Sch. Mines Quar. 70(4).

542. Bengson, S. A.
1976. How drip irrigation revegetates mine wastes in an arid environment. Mining Eng. 28:45-46.

Bengson discusses advantages and disadvantages of a drip irrigation for revegetation in arid environments. Advantages include: reduces hazard of runoff and erosion and promotes vigorous plant responses. Disadvantages include: cost, spatial arrangement of plants (linear), and inefficient for establishing solid plant cover. Drip irrigation is a helpful tool for some revegetative problems but not for all situations.

543. Bjugstad, A. F.
1977. Reestablishment of woody plants on mine spoils and management of mine water impoundments: an overview of Forest Service research on the northern High Plains. In The reclamation of disturbed lands. p. 3-12. Robert A. Wright, ed. Univ. N.Mex. Press, Albuquerque.

544. Bourdo, E., and G. Willis.
1975. Borrow pit reforestation. Mich. Tech. Univ. Res. Note 17, 8 p. L'anse, Mich.

Along the highways of the Upper Peninsula, numerous acres have been stripped for rill, gravel, or crusher rock. Although most pits are of limited size (less than 40 acres), the sum total of the area concerned amounts to thousands of acres. Some pits have not become reforested after more than 50 years. To test the feasibility of reforesting such an area, a Ford Forestry Center "borrow pit" was planted with a variety of tree species, native and introduced, to determine which were best adapted for growth on coarse gravelly materials from which topsoil had been stripped.

545. Brown, D.
1977. Equipment for reclaiming strip mined lands. USDA For. Serv., Equip. Develop. Cent. Handb. 7728-2503, 58 p. Fort Missoula, Mont.

546. Brown, L. F.
1976. Reclamation at Climax, Urad and Henderson Mines. Mining Congr. J. 62(4):42-43.

The three Amax Inc. molybdenum mines in Colorado have had active reclamation programs for years. The company began tailings revegetation research in 1965 at the Climax Mine near Leadville. The research is extremely important because all three mines are at timberline along the Continental Divide. Mine elevations range from 10,300 to 11,300 ft above sea level. These altitudes result in severe winters and very short growing seasons. The average annual temperature is slightly below freezing. The growing season, as depicted by consecutive frost-free days, can be expected to last only 6 to 8 weeks. Seed of grass species native to these

elevations is not commercially available. Therefore, much of the company's research has been directed toward determining which commercially available seed species are adaptable to these extreme conditions. The oldest high-altitude-species adaptation plots in Colorado are at the Climax Mine. Reclamation at each mine must be approached differently. Each mine has a unique history and a different status with respect to future production and environmental planning.

547. Brown, R. W., and R. S. Johnston.
1976. Revegetation of alpine disturbances. Range Guide 2(2):2-3.

548. Brown, R. W., and R. S. Johnston.
1976. Revegetation of an alpine mine disturbance: Beartooth Plateau, Montana. USDA For. Serv. Res. Note INT-207, 8 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

The first-year results of revegetation research on an alpine mine disturbance on the Beartooth Plateau in Montana are discussed. Plant densities were highest on plots treated with topsoil and fertilizer. Native seed mixtures produced higher plant densities than did introduced seed mixtures on both topsoil and raw spoil plots. Transplanting of native plants was also studied as an alternative revegetation technique. All transplants survived after 1 year, suggesting that this method offers an excellent opportunity for plant establishment on alpine disturbances.

549. Brown, R. W., and R. S. Johnston.
1978. Rehabilitation of a high elevation mine disturbance. In Proc. Workshop on Revegetation of High Altitude Disturbed Lands. p. 116-130. Colo. State Univ. Infor. Series No. 28.

Since Harrington's (1946) early efforts on Trail Ridge in Colorado, very little research has been devoted to the development of high elevation revegetation methods. This research was initiated on the Beartooth Plateau in 1972 to develop rehabilitation methods. Studies included several different aspects of rehabilitation such as consideration of (1) plant succession, (2) species adaptability, (3) characterization of microenvironmental factors, including soils and hydrologic phenomena (see Johnston and others 1975), (4) revegetation trials by seeding and transplanting (see Brown and Johnston 1976; Brown and others 1976), and (5) laboratory bioassays. During the 1976 growing season the combined results of these various studies were applied to a larger scale rehabilitation demonstration effort on the McLaren Mine in the Beartooth Mountains of Montana. The objective of this effort was to develop a rehabilitation plan which would lead to the establishment of a stable plant cover on relatively sterile acid-producing spoils in a high elevation environment. Also, it was intended to demonstrate that the results from small revegetation plots and other studies could be applied to large scale rehabilitation efforts.

550. Brown, R. W., R. S. Johnston, and D. A. Johnson.
1978. Rehabilitation of alpine tundra disturbances. J. Soil Water Conserv. 33:154-160.

Alpine tundra is defined and the extent and nature of disturbances reviewed. Twelve percent of alpine tundra requires rehabilitation. Characteristics of the alpine tundra are discussed, including climate, geology, soils, and vegetation. The paper includes a section on the adaptations required by plants (growth form, drought resistance). Plant breeding potential is reviewed. A section on rehabilitation recommendations is included. Contouring, shaping, plant species selection, time of seeding, fertilizer, and other soil treatment and postplanting management are covered.

551. Brown, R. W., and R. S. Johnston.
1978. Rehabilitation of disturbed alpine rangelands. In Proc., First Int. Rangeland Congr. p. 704-706. Soc. Range Manage., Denver, Colo.

552. Brown, R. W., and R. S. Johnston.
1979. Revegetation of disturbed alpine rangelands. In Special management needs of alpine ecosystems. p. 76-94. D. A. Johnson, ed. Soc. Range Manage., Range Sci. Series No. 5.

553. Brown, R. W., R. S. Johnston, and K. Van Cleve.
1978. Rehabilitation problems in alpine and arctic regions. In Proc. Symp., Reclamation of Drastically Disturbed Lands. p. 23-44. Am. Soc. Agron., Madison, Wis.

This paper provides a comprehensive summary and discussion of the nature and extent of the problems in rehabilitation of tundra. Type and extent of disturbance are discussed. Environmental factors affecting rehabilitation including climatic facts, geology, and soils are covered. There is a comprehensive section on plant species adaptability and selection. Recommended techniques for rehabilitation are given.

554. Brown, R. W., R. S. Johnston, B. Z. Richardson, and others.
1976. Rehabilitation of alpine disturbances: Beartooth Plateau, Montana. In Proc., Workshop on Revegetation of High Altitude Disturbed Lands. p. 58-73. Colo. State Univ., Fort Collins, Infor. Series No. 28.

The current research program in the rehabilitation of alpine disturbances was begun in 1972, and has since been incorporated into the SEAM (Surface Environment and Mining) Program of the USDA Forest Service. The research program has grown to include the following activities: (1) revegetation research on disturbed sites including seeding, species trials, and transplanting; (2) plant succession on disturbed sites; (3) physiology of plants on disturbed sites; (4) water quality research, including surface water quality, soil water chemistry, and impact of roads on storm regimen and water quality; (5) microenvironmental characteristics of alpine disturbance; and (6) snow accumulation and melt related to micro- and macro-surface configurations of mine surfaces.

555. Burdick, M. D.
1974. SCS and the oil shale program. Soil Conserv. 40(11):4-6,18.

556. Butterfield, R. I.
1977. The revegetation potential of the Leviathin Mine spoils. M.S. thesis. Univ. Nevada, Reno. 72 p.

557. Conwell, C. N.
1975. Reclaiming mined lands in Alaska. Am. Inst. of Mining, Metallurgical, and Petroleum Eng., Soc. of Mining Eng. preprint 75-AO-304, 10 p.

558. Cook, C. W.
1974. Surface rehabilitation of land disturbances resulting from oil shale development. Colo. State Univ., Environ. Resour. Cent., Fort Collins, Infor. Series 11, 56 p.

559. Cook, C. W.
1976. Surface-mine rehabilitation in the American West. Environ. Conserv. 3(3):179-183.

560. Cundell, A. M.
1977. The role of microorganisms in the revegetation of strip-mined lands in the western United States. J. Range Manage. 30(4):299-305.

561. Dai, T. S., and A. Langevin.
1978. Revegetation activities - 1977. 54 p. Syncrude Canada Ltd.

The 1977 revegetation activity is a continuation of the reclamation program that commenced on disturbed lands in 1976. The majority of the area treated was disturbed as a result of water diversion projects and construction activity. Activities in 1977 included site preparation, seeding and fertilizing, and postseeding treatment in the form of reseeding in erosion areas and application of fertilizer for vegetation maintenance. A total of 175 ha (429 acres) were treated as primary revegetation sites and 147 ha (364 acres) as secondary treatment. Selection of seed and fertilizer for the 1977 program was based on the previous year's plant performance and soils evaluation. Reforestation trials were initiated in select locations to provide preliminary data on woody plant establishment, planting techniques, and survival rates.

562. Day, A. D., and K. L. Ludeke.
1973. Stabilizing copper mine tailing disposal berms with giant bermudagrass. J. Environ. Qual. 2(2):314-315.

563. Day, A. D., and others.
1976. Copper mine wastes: good potential as medium for growing livestock forage. Eng. and Mining J. 177(2):90-91.

564. Day, A. D., K. L. Ludeke, and T. C. Tucker.
1977. Influence of soil materials in copper mine wastes on the growth and quality of barley grain. J. Environ. Qual. 6(2):179-181.

Experiments were conducted in Arizona to study the effects of four soil materials in copper mine wastes (desert, overburden, tailing-overburden, and tailing) on the growth, grain yield, and grain quality of barley. Barley was effective in the revegetation and stabilization of the four soil materials in Cu mine wastes. It also provided needed organic material to be incorporated into the surface 15 cm, which created a more suitable soil medium for the establishment of perennial grass species. When grown in desert soil and overburden, barley produced taller plants, more vegetative plants, higher grain yields, and grain of higher quality than when it was produced in tailing-overburden and tailing soil materials. Barley can be used effectively to produce satisfactory grain yields and grain of suitable quality for livestock and wildlife and feed in the rehabilitation of desert soil, overburden, tailing-overburden, and tailing soil materials in copper mine wastes.

565. Dean, K. C., R. Havens, and K. T. Harper.
1969. Chemical and vegetative stabilization of a Nevada copper porphyry mill tailing. 18 p. U.S. Bur. Mines, Washington, D.C.

The Bureau of Mines stabilized 10 acres of windblown copper mill tailings at McGill, Nev., by a combination chemical-vegetative procedure. Legumes, winter wheat, wheatgrasses, and wild rye were seeded, and the area was subsequently sprayed with a resinous adhesive chemical to stabilize the sands until the vegetation could grow. During the year since treatment, the area has been well stabilized against wind erosion. The established vegetation appears to be capable of self-perpetuation and renewal without irrigation. The cost of stabilizing the area was $135.50 per acre.

566. Deichmann, J. W., and L. D. Potter.
1977. Environmental factors affecting natural succession on coal mine spoils. Final Rep., contract 16-552-CA, 58 p. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins.

567. Donovan, R. P., R. M. Felder, and H. H. Rogers.
1976. Vegetative stabilization of mineral waste heaps. 318 p. Research Triangle Inst., Research Triangle Park, N.C. [Available NTIS as PB-252 176/3ST.]

The report reviews the establishment of vegetative cover as a candidate method for reclaiming mineral ore waste heaps. It begins by describing the location and properties of spoils and tailings from mining and ore beneficiation, and briefly reviews present methods for controlling dust emissions from them. Most of the report develops fundamentals for establishing vegetative cover, and gives a detailed review of case histories of both successful and unsuccessful revegetation. The report also contains a catalog of individual plant species. This mass of information can be used to provide general guidelines for establishing vegetative cover.

568. Eddleman, L., and P. Doescher.
1978. Selection of native plants for spoils revegetation based on regeneration characteristics and successional status. In Land reclamation program, annual rep. p. 132-134. Argonne Natl. Lab., Argonne, Ill.

569. Eddleman, L., and P. L. Meinhardt.
1977. Indigenous plants of southern Montana. I. Viability and suitability for reclamation in the Fort Union Basin. Mont. For. and Conserv. Exp. Stn., Univ. Mont., Missoula, Spec. Publ. 4, 122 p.

570. Eddleman, L., and P. L. Meinhardt.
1978. Survey of viability of indigenous grasses, forbs, and shrubs. U.S. Dep. Energy, Annu. Prog. Rep. 183, 48 p.

571. Eddleman, L., P. L. Meinhardt, and P. S. Doescher.
1977. Selection of native plants for spoils revegetation based on regeneration characteristics and succession of status. 97 p. Completion Rep., Argonne Natl. Lab., Argonne, Ill.

572. Engineering and Mining Journal.
1970. Cyanamid shoots for instant reclamation of mined lands. Eng. and Mining J. 171(1):90-92.

A novel land reclamation technique practiced by American Cyanamid Co., at its open pit operations in Florida, consists of disposing flotation and slime tailings in mined out areas in a way that produces quick compaction and better water recovery.

573. Everett, H. W.
1974. Progress in stabilizing manganese mine spoil. Soil Conserv. 40(1):19-20.

574. Farmer, E. E., and W. G. Blue.
1978. Reclamation of lands mined for phosphate. In Reclamation of Drastically Disturbed Lands. p. 585-608. F. W. Schaller and P. Sutton, eds. Agron. Soc. Am., Crop Sci. Soc. Am., Soil Sci. Soc. Am., Madison, Wis.

This paper reviews current technology and know-how for reclamation of phosphate-mined lands. Problems which are not being approached nor worked on are identified. Preventable revegetation failures are identified and corrective measures given. Recommended treatments of fertilizer, topsoil, irrigation, and mulch are covered. Seeding mixtures and rates are also covered. Climatic variations and plant resources are also reviewed.

575. Farmer, E. E., R. W. Brown, B. Z. Richardson, and others.
1974. Revegetation research on the Decker coal mine in southeastern Montana. USDA For. Serv. Res. Pap. INT-162, 12 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

First-year results of revegetation research at the Decker coal mine in southeastern Montana are described. Three types of main plots were located on overburden material: (1) a control plot, (2) an irrigated plot, and (3) a plot dressed with topsoil materials. Each main plot consists of 48 subplots for a total of 144 subplots. Treatments included different grass mixtures, fertilizer, and mulch on irrigated and unirrigated plots. On the basis of dry-weight grass production, several treatments produced acceptable first-year grass stands. The top-dressing of mine overburden appears to be a highly desirable revegetation practice. Generally, wheatgrasses (*Agropyron* spp.) have dominated the dry-weight production.

576. Farmer, E. E., B. Z. Richardson, and R. W. Brown.
1976. Revegetation of acid mining wastes in central Idaho. USDA For. Serv. Res. Pap. INT-178, 17 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

The results of 2 years of revegetation research on acid mining wastes in central Idaho are described. Three types of main plots were used, each containing 12 treatments. Treatments are evaluated in terms of both vegetative production and ground cover. Vegetative species are evaluated in terms of their density and persistence under different treatment conditions. Coupled with a fertilization program, top-dressing of mining wastes with selected overburden materials appears to be a highly desirable revegetation practice.

577. Fitter, A. H., and A. D. Bradshaw.
1974. Responses of *Lolium perenne* and *Agrostis tenius* to phosphate and other nutritional factors in the reclamation of colliery shale. J. Appl. Ecol. 11(2):597-608.

578. Grigg, N. S.
1976. Precipitation management for reclamation of overgrazed areas in arid and semi-arid regions. 13 p. Colo. Environ. Resour. Cent., Fort Collins. [Available NTIS as PB-251-166.]

An investigation was made of the feasibility of utilizing precipitation management as a method for the vegetative restoration of strip mine spoils in arid and semiarid areas, and for the economic and environmental improvement of reclaimed mine spoils. The procedure is believed to be capable of producing vegetative systems of higher economic and wildlife habitat value than exists naturally on these same lands or might be produced by other nonirrigated methods. It would appear that the cost of the necessary Research and Development program would be minimal, particularly when compared with the potential economic, environmental, and social benefits that would accrue.

579. Harbert, H. P., III, and W. A. Berg.
1978. Vegetative stabilization of spent oil shales: vegetation moisture salinity and runoff, 1973-76. 183 p. Colo. State Univ., Fort Collins. [Available NTIS as PB-280 308/8ST.]

Disposal of massive amounts of spent shale will be required if an oil shale industry using surface retorting is developed. Field studies were initiated in 1973 on two types of spent oil shale--coarse-textured (USBM) and fine-textured (TOSCO). The objectives of these studies were to investigate surface stability of and salt movement in spent shales and spent shales covered with soil after vegetation has been established by intensive treatment and then left under natural precipitation conditions. The plots were established at low-elevation (1 700 m) and high-elevation (2 200 m) study sites in northwestern Colorado. A good cover of native species was established on all plots by leaching, N and P fertilization, seeding, mulching, and irrigation. High levels of Mo were found in plants grown in the spent shales compared to plants grown in soil. Resalinization occurred following leaching of the TOSCO spent shale. The greatest runoff was from the TOSCO spent shale. Runoff was moderately to highly saline.

580. Harris, M. M., and M. F. Jurgensen.
1977. Development of *Salix* and *Populus* mycorrhizae in metallic mine tailings. Plant and Soil 47(2):509-517.

581. Hogan, G. D., G. M. Courtin, and W. E. Rauser.
1977. Copper tolerance in clones of *Agrostis gigantea* from a mine waste site. Can. J. Bot. 55(8):1043-1050.

582. Hortenstine, C. C., and D. F. Rothwell.
1972. Use of municipal compost in reclamation of phosphate-mining sand tailings. J. Environ. Qual. 1(4):415-417.

583. Howard, G. S., G. E. Schuman, and F. Rauzi.
1977. Growth of selected plants on Wyoming surface-mined soils and flyash. J. Range Manage. 30(4):306-310.

584. Howard, P. L.
1978. Plant succession studies on sub-alpine acid mine spoils in the Beartooth Mountains. M.S. thesis. Utah State Univ., Logan. 93 p.

585. Johnson, M. S.
1976. Plant growth on fluorspar mine tailings. J. Soil Water Conserv. 31(1):17-20.

586. Johnson, M. G., A. D. Bradshaw, and J. F. Handley.
1976. Revegetation of metalliferous fluorspar mine tailings. Inst. Mining and Metallurgy Trans. 85:A32-A37.

Waste materials produced during the processing of raw mineral ore containing fluorspar are deposited in large tailings dams whose impact on the surrounding countryside may be reduced considerably by a vegetation cover on the tailings. The experimental trials carried out to determine the effects on plant growth of heavy metals in fluorspar tailings indicate that the major limitations to plant growth were the very low levels of nitrogen and phosphorus. It appears that a seed mixture with a high legume content, supplied with adequate phosphorus, is the key to the development of a low-maintenance permanent-cover vegetation on the tailings dam.

587. Johnson, M. S., T. McNeilly, and P. D. Putwain.
1977. Revegetation of metalliferous mine spoil contaminated by lead and zinc. Environ. Pollution 12(4):261-277.

588. Johnston, R. S., R. W. Brown, and J. Cravens.
1975. Acid mine rehabilitation problems at high elevations. Symp. Proc., Watershed Manage., Am. Soc. Civil Eng. p. 66-79. Utah State Univ., Logan.

A multiagency study of problems associated with alpine and subalpine mining activity has been initiated at several sites near Cooke City, Mont. With cooperation from mine owners and lessees, a demonstration project of mine disturbance rehabilitation techniques has been funded by the Environmental Protection Agency and is administered by the State of Montana, Department of Natural Resources and Conservation. The purpose of the project is to demonstrate the adaptability of existing technology to solve mining problems in the alpine and subalpine zones. These rehabilitation problems include: the reduction or elimination of acid mine drainage; slope stabilization to reduce erosion and sedimentation; revegetation of disturbed areas; and elimination of the visual impact of mining in a heavily used recreation area. Large amounts of inventory data are being assembled as part of the problem evaluation.

589. Jonas, R. S., and W. C. Sharp.
1970. Conservation action: greenbacks bring green back to gravel mines. Soil Conserv. 35(9):208.

590. Kaiser Sand and Gravel Company.
1973. Kaiser random land reclamation project. 16 p. [Authorized reprint by Natl. Sand and Gravel Assoc.]

591. Keller, H., and J. C. Leroy.
1975. The systematic reclamation of gold mine tailings. Can. Mining J. 96:45-46.

Erocon's work is the reclamation of mine wastelands. It has considerable experience particularly in the reclamation of gold mine tailings in the Canadian Shield since the latter part of the sixties when most gold mines were closing down. A well developed continuous vegetation cover has a remarkable regulatory effect on natural precipitation. The latter can be highly destructiv on unprotected tailings and slime ponds. The established vegetation will be able to cope with heavy precipitation, practically eliminating the immediate surface runoff and its resulting deep erosional features, overload sedimentation of streams, landslides, mudflows, contamination of water with freed toxic fluids, etc. The developing vegetation cover will cause the tailings to become firm, will create a soil and provide well drained flatlands, which can be a definite asset in some rugged areas of the Canadian Shield. Nurseries, sod farms, cattle farms, recreation areas, and golf courses are considered as some of the ultimate uses of these so-called "wastelands."

592. Kelley, N. E.
1978. Vegetational stabilization of uranium spoil areas, Grants, New Mexico. Ph.D. diss. Univ. N.Mex., Albuquerque. 89 p.

593. Kenny, S. T., ed.
1978. Proceedings: High Altitude Revegetation Workshop No. 3. Colo. Water Resour. Res. Inst., Infor. Series No. 28, Colo. State Univ., Fort Collins.

Topics included are ecology of alpine plants; problems in the identification of threatened and endangered species; political and economical implications of reclamation; plant materials development construction and design techniques; etc.

594. Kneib, W. A.
1978. Manure additions improve revegetation success on amended mine spoils. M.S. thesis. Utah State Univ., Logan. 138 p.

595. Kremmel, D. G.
1976. Chemical additives as an aid in reclamation programmes. In Proc., Seminar on Landscaping and Land Use Planning as Related to Mining Operations [Mar.-Apr. 1976]. p. 251-257. Australas. Inst. Mining and Metallurgy, Victoria, Austr.

The prevention of erosion from slopes, banks, and batters following open cut mining is an area in which chemicals are being successfully used to achieve the desired results. Most of these products can be classified under one of the following three broad categories: neutral fibrous agents, such as straw, hay, wood shavings, burlap, cloth, tires, and wood mats; synthetic and polymeric materials, such as latex and epoxy compounds, crosslinked polymers, linear polymers crosslinked in place, drying oils, and bitumen; rocks and silicates, such as gravel, riprap, and sodium silicates.

596. Lagerwerff, J. V., and W. D. Kemper.
1975. Reclamation of soils contaminated with radioactive strontium. Soil Sci. Soc. Am. Proc. 39(6):1077-1080.

Evesboro loamy sand, Sassafras sandy loam, and Fort Collins silt loam were treated with a mixed Ca-Sr solution to give about 95 percent saturation with Ca and 5 percent saturation with Sr. Samples of these soils were placed in acrylic cylinders and leached with 0.06N $CaCl_2$ to remove Sr. The leachings were mechanically controlled at various rates for different periods of time. Extracting the leached soil samples with 1N HCl yielded residual Sr equal to 0.43, 0.47, and 0 percent of the Sr exchange capacity of the Evesboro, Sassafras, and Fort Collins soils, respectively. There was general agreement between Sr concentrations measured at various depths and those calculated on the basis of the Lapidus-Amundson equation, especially so with heavier soils. The Evesboro and Fort Collins soils were also tagged with carrier-free Sr85 and, mounted in columns, leached with 0.06N solutions of either $CaCl_2$ or $SrCl_2$. The removal of Sr85 was more complete from the Evesboro than from the Fort Collins soil, and from the center than from the edge of the columns. Short-term leaching capability of $SrCl_2$ exceeded that of $CaCl_2$ where Sr85 was present in amounts small enough to be absorbed mostly on specific soil absorption sites. Where larger amounts of Sr85 had been absorbed, Ca was as equally effective as Sr in replacing the contaminant.

597. Land Rehabilitation Advisory Board, Department of Soil Conservation.
1973. Recommendations for establishment of vegetation on surface mined areas, Des Moines, Iowa. 13 p.

This paper is a handbook on recommended techniques for establishment of vegetation on surface mined areas of Iowa. Subjects covered include: site preparation, soil testing, lime requirements, fertilization, seedbed preparation, time of seeding, seeding mixtures and rates, establishment of trees and shrubs, and weed control.

598. Langevin, A., and P. D. Lulman.
1977. Revegetation activities - 1976. 79 p. Syncrude Canada Ltd.

During the spring of 1976, the first year of revegetation on Syncrude Lease #17, approximately 138 ha (340 acres) of land were treated for revegetation. The land was handed over by project construction in a shaped and graded condition suitable for immediate seeding. The prime objective of the program has been to create a viable vegetation cover, minimizing erosion of exposed surface soil. The 1976 revegetation program has been carried out cooperatively by Operations-Conservation and Environmental Affairs. Following application, field plots were set up on all major areas treated in 1976. Results from these plots have demonstrated a need for a less diverse seed mixture applied at lower rates per acre. Nitrogen is the major limiting nutrient in soil and appropriate fertilizers are recommended to correct this deficiency. A two-phase approach to hydroseeding and mulching is recommended for most effective use of mulch. "Rough" seedbeds, harrowed or tilled, are more conducive to rapid germination and strong establishment of vegetation than smoothly graded surfaces. Clay is an essential ingredient for maintenance of seedbed fertility.

599. Lawrence, E. A.
1974. Summary of vegetation program on lead-zinc tailings. Am. Inst. Mining, Metallurgical, and Petroleum Eng., Soc. Mining Eng., Trans. 256(4):306-307.

600. Lewis, J. W.
1976. Regeneration of coastal ecosystems after mineral sand mining. Austr. Mining 68(7):27-29.

601. Lindstrom, G. A.
1960. Forestation of strip-mined land in the Central States. USDA For. Serv., Agric. Handb. 166, 74 p. Washington, D.C.

602. Ludeke, K. L.
1973. Stabilizing copper mine tailing disposal berms with giant bermudagrass. J. Environ. Qual. 2(2):314-315.

603. Ludeke, K. L.
1973. Vegetative stabilization of tailings disposal berms. Mining Congr. J. 59:32-39.

604. Ludeke, K. L.
1976. Evaluation and selection of spring barley (*Hordeum vulgare* L.) for the revegetation and stabilization of copper mine tailing disposal berms. Ph.D. diss. Univ. Ariz. 68 p. [Diss. Abstr. Int. 37/06B:2612.]

605. McMillan, H., and R. Carlson.
1975. Using wastewater solids to reclaim strip-mined land. Trans. Soc. Mining Eng. AIME 258(4):273-278.

Land application as a method of using the solids produced in the wastewater treatment process and demonstrations on farmland, reclamation of acid strip-mine spoils, fertilizing a landfill, and reclamation of an alkaline sand waste pit are discussed and presented in tabular and graphical form.

606. May, J. T.
1975. Renewal of china clay strip mining spoil in southeastern United States. In The ecology of resource degradation and renewal. [Brit. Ecol. Soc., 15th Symp., Univ. of Leeds, Yorkshire, July 10-12, 1973, Proc.] p. 351-361. John Wiley and Sons, New York. 480 p.

607. May, J. T.
1977. Highlights of a decade of research and reclamation of kaolin clay strip mining spoil, 1966-1976. Georgia For. Res. Counc. Rep. 37, 36 p.

This paper reviews the research on reclamation and revegetation of kaolin clay spoils, including a section on industry innovations. Spoil properties and soil genesis, hydroseeding, aerial seeding, and tree planting studies are covered. The summary includes recommended fertilization, planting techniques, ground cover and tree establishment, and useful plant species.

608. May, J. T., C. L. Parks, and H. F. Perkins.
1973. Establishment of grasses and tree vegetation on spoils from kaolin clay strip-mining. In Ecology and reclamation of devastated land, vol. 2. p. 137-147. Gordon & Breach, New York.

609. May, M.
1975. Reclamation of uranium-mined areas in the United States. In The ecology of resource degradation and renewal. [Brit. Ecol. Soc., 15th Symp., Univ. of Leeds, Yorkshire, July 10-12, 1973, Proc.] p. 223-230. John Wiley and Sons, New York. 480 p.

610. Meecham, J. R., and L. C. Bell.
1977. Revegetation of alumina refinery wastes: (2) glasshouse experiments. Austr. J. Exp. Agric. 17(87):689-696.

611. Michelutti, R.
1974. How to establish vegetation on high iron-sulphur mine tailings. Can. Mining J. 95(10):54-58.

612. Mine and Quarry.
1978. Reclamation landscaping with drip irrigation. Mine and Quarry 7(4):38,40,43,45.

613. Mitchell, W. W.
1972. Adaptation of species and varieties of grasses for potential use in Alaska. In Proc., Symposium on Impact of Soil Resource Development on Northern Plant Communities [Aug. 1972, Univ. Alaska.] p. 2-6. Institute of Arctic Biology, Univ. Alaska, Fairbanks.

Overview is presented of revegetation research in diverse areas of Alaska. Many grasses have proved successful in tests on mesic boreal sites of southern to central interior Alaska. Dry sites are limiting because of moisture conditions but less restrictive than more moist, peaty sites. The latter generally are acidic. Fewer grasses are successful on these sites. Tundra regions with their cooler, shorter growing seasons, are the most limiting. Alpine tundra is more favorable for growth than arctic tundra. Certain fescues, bluegrasses, meadow foxtail and timothy have demonstrated wide adaptability in Alaska. Alaskan soils require applications of N, P, and K for satisfactory stand establishment. Rates and ratios become more critical on peaty soils where disease problems may also affect winter survival. Native taxa offer good potential for revegetation material that would be more durable and require less maintenance than introduced taxa. Limited material is available now, but work is progressing at the agricultural institute to provide other, widely adapted materials.

614. Mitchell, W. W.
1973. Alaskan climatic and ecological patterns as related to revegetation possibilities. In 1973 Alaska Revegetation Workshop Notes. p. 51-56. Univ. Alaska, Fairbanks.

Broad patterns of vegetation and climate are discussed in relation to revegetation possibilities. Observations and experiences of the author on vegetational responses to climatic conditions of harsh Alaska sites from coastal rain forests to arctic and maritime tundra are given.

615. Mitchell, W. W.
1973. Using plant resources for conservation. Agroborealis (July 1973):24-25.

Mitchell's research on revegetation of a maritime tundra in Alaska has shown that native plants (such as Bering hairgrass) offer real potential for conservation in the North.

616. Mitchell, W. W.
1976. Revegetation research on Amchitka Island, a maritime tundra location in Alaska. U.S. Energy Res. and Develop. Admin., Nev. Oper. Off., NVO-172, 59 p.

Revegetation studies commenced by the Alaskan Agricultural Experiment Station in 1970 on Amchitka Island culminated in 1973 with the seeding of disturbed areas associated with the nuclear testing program. Cool temperatures coupled with strong winds and a high incidence of fog and cloud cover impose a tundra aspect on Amchitka. Twenty-two perennial grasses, two clovers, and four annual grasses were tested on different soil types at low to medium-high (480 ft) elevation sites. At higher elevations severe winds and frost action maintain a barren-ground aspect. Relatively humid, acidic sites were the least favorable, a test site gravel pad the most favorable. The revegetation seeding mix included Boreal red fescue, Highlight chewing fescue, Bering hairgrass, and annual ryegrass. Fertilization was necessary to establish plants on most sites.

617. Mitchell, W. W.
1977. Arctic revegetation research. In Northeast by east: review of Alaskan arctic gas research, vol. 2, no. 3. 5 p. Alaskan Arctic Gas Study Co., Anchorage, Alaska.

Both native Alaskan grasses and grasses from the boreal to temperate region were tested at revegetation trials established on the arctic gas test pipe facility at Prudhoe Bay. Seventeen species of perennial grasses were tested. Selections of arctic grass, fluejoint reed grass, and a bluegrass are now being developed for commercial production.

618. Mitchell, W. W.
1977. Grasses for revegetation in the Arctic. In Proc., Symp., Surface Protection through Prevention of Damage (Surface Management). p. 141-147. The Arctic Slope BLM State Office, Alaska.

The topic is limited to grasses applicable for use on the Arctic Slope. Prior work on native plants at the Palmer Research Station gave impetus to the particular needs for research in the Arctic. Trials began there in 1969, and some plots still being monitored are now 6 years old. Materials of Alaskan origin or development in Alaska have been the most successful. Those tested from other northern regions have been found waning. The research has led to the development of three new grass varieties from native plant sources.

619. Mitchell, W. W.
1978. Development of plant materials for revegetation in Alaska. In Proc., High Altitude Revegetation Workshop No. 3 [Mar. 1978, Fort Collins, Colo.]. p. 101-115. Colo. State Univ., Fort Collins.

This paper reviews the factors (mostly climatic) which limit revegetation success in Alaska. A list of successful plant material is given. A number of native Alaska species are presently being developed for commercial production. Native species demonstrate a high degree of variability; thus selection efforts are necessary to identify populations that possess appropriate adaptations.

620. Monsen, S. B., and D. R. Christensen.
1975. Woody plants for rehabilitating rangelands in the Intermountain Region. In Wildland Shrubs Symposium and Workshop Proceedings [Provo, Utah]. p. 72-119. H. C. Stutz, ed. Brigham Young Univ., Provo, Utah.

Considerable variability among separate collections, ecotypes, and subspecies has been observed for most shrubs, and these differences have been used to promote the development of superior traits. The forage qualities of various shrubs have been markedly improved through the selection and propagation of palatable and productive collections. Plants that occur over a wide geographical range provide an extensive base of genetic material for breeding and selection. However, endemic collections have also demonstrated adaptability to a wide range of planting sites. Most shrubs that are useful as forage plants have proved to be well adapted to restoring other wildland sites, particularly disturbed roadways, mine spoils, and recreation facilities.

621. Moore, T. R., and R. C. Zimmermann.
1977. Establishment of vegetation on serpentine asbestos mine wastes, southern Quebec, Canada. J. Appl. Ecol. 14(2):589.

622. Moseley, J. R., and L. D. Potter.
1978. Ecological parameters of fourwing saltbush in relation to mine spoil reclamation. Final rep., contract 16-551-CA, 50 p. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

623. Moudgil, B. M.
1976. Mined land reclamation by the Florida phosphate industry. Trans. Soc. Mining Eng. AIME 260(2):187-191.

During hydraulic processing of phosphate matrix enormous amounts of phosphate slimes are produced. Significant portions of mined land are utilized to sort the slimes. Some dewatering of the slimes is essential before any reclamation of the storage ponds can be undertaken. Dewatering and reclamation of slime storage ponds pose many problems which are not encountered in reclamation of other mined areas.

624. Mulamoottil, G., and R. Farvolden.
1975. Planning for the rehabilitation of gravel pits. Water Resour. Bull. 11(3):599-604.

625. Murray, D., and D. Moffett.
1977. Vegetating the uranium mine tailings at Elliot Lake, Ontario. J. Soil and Water Conserv. 32(4):171-174.

626. Mustard, E. W.
1977. From mess to marsh land reclamation, gravel mine to wildlife sanctuary, Colorado. Soil Conserv. 42(8):8-9.

627. Newey, C. O., and J. W. Lewis.
1976. Landforms and revegetation after mineral sand mining. In Proc., Seminar on Landscaping and Land Use Planning as Related to Mining Operations [Mar.-Apr. 1976]. p. 205-217. Austr. Inst. Mining and Metallurgy, Adelaide Br. (Symp. Ser. No. 13), Barkville, Victoria.

The mineral sand ore bodies of the east coast of Australia occupy approximately 3 percent of the dune-heath-wetland coastal environment. They are associated with coastal plant communities ranging from Holocene high dunes carrying mature eucalypt forests to low-lying heaths on Pleistocene deposits. Commonly, 0.25 to 1.5 percent of the sand volume mined is removed from the site. Therefore, the volume change is insignificant. The equipment and techniques in use are flexible and the land can be returned in a manner suited to its subsequent use for grazing, subdivision, or recreation. Landforms similar to the pre-existing are created in two case studies given. Sophisticated revegetation techniques are practiced and are discussed in two case studies. Premining vegetation surveys and postmining monitoring are used to guide the management of the ecosystem.

628. Nielson, R. F., and H. B. Peterson.
1972. Treatment of mine tailings to promote vegetative stabilization. Utah State Univ., Logan, Agric. Exp. Stn. Bull. 485, 22 p.

This paper summarizes 6 years research relating to problems in stabilization of mine tailings with revegetation. Laboratory, greenhouse, and field studies are discussed. Tailings are highly variable in physical and chemical properties. Excessive soluble salts, oxidation of pyrites leading to acidification, and heavy metal toxicity are problems that are covered. Tailings are also deficient in plant nutrients and subject to severe wind erosion. Fifty-nine plant materials were evaluated to determine their adaptation to tailings. None showed unique adaptability.

629. O'Neill, T. J., and F. S. Matter.
1976. Recycling Arizona land after copper mining. Soc. Mining Eng. AIME, reprint 76-K-336, 16 p.

630. Oxford, T. P., and L. G. Bromwell.
1977. Planning for phosphate land reclamation. In Proc., Conference on Geotechnical Practices for Disposal of Soild Waste Matter [Univ. Mich., Ann Arbor, June 13-15, 1977]. p. 715-726. Am. Soc. Civil. Eng., New York.

This paper describes considerations involved in the development of a life-of-mine plan for the disposal of wastes and the restoration of land to benefical use for a future mining tract in central Florida. The arrangement and cost of waste clay settling areas, minimization of disturbance to unmineable areas, the interface between the operation and the surrounding community, the presence of wetland areas, and the selection of reclamation techniques are among the concerns addressed.

631. Packer, P. E.
1974. Rehabilitation potentials and limitations of surface-mined land in the Northern Great Plains. USDA For. Serv. Gen. Tech. Rep. INT-14, 44 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

This survey and analysis of rehabilitation experience and potentials of the major coal and bentonite surface mines in the Northern Great Plains indicate several rather common problems. Perhaps the most common is leaving steep spoil slopes on unstable soil associations. Rilling and gullying start quickly, particularly where spoils have high sodium contents. Such erosion washes seed and fertilizer from areas that need revegetation. The author believes that almost all the surface-mined lands of the Northern Great Plains can be rehabilitated successfully. However, a large amount of basic information needs to be collected, and numerous research problems require solutions before such rehabilitation can proceed expeditiously, effectively, and economically.

632. Packer, P. E., C. E. Jensen, E. L. Noble, and others.
1979. Estimating revegetation potentials of land surface mined for coal in the West. In Ecology and resource development, vol. 1. p. 396-411. M. K. Wali, ed. Pergamon Press, New York.

633. Peplow, E. H., Jr.
1970. Western mining's land restoration efforts. Mining Congr. J. 56(9):59-63.

634. Persse, F. H.
1975. Strip-mining techniques to minimize environmental damage in the upper Missouri River Basin states. 58 p. U.S. Bur. Mines, Denver, Colo. [Available NTIS as PB-245-843.]

Geology, climate, and current land use information in the upper Missouri River Basin are presented to assist strip-mining and strip-mining land reclamation operations. Proven methods of air and water pollution control and mined land restoration are described along with untried methods and equipment for land reclamation. The semiarid climate of the upper Missouri River Basin necessitates suppression of dust for the well-being of both men and machinery. However, current air pollution control methods are expected to satisfy these needs in most instances. The prevention of water pollution at coal and lignite operations generally would include diverting surface water from the working area without increasing sedimentation or dissolved salt content, measuring all water entering and leaving the mine area, and constructing a settling basin for mine water containing sediments, which are to flow in a water course. Reclamation of strip-mined land will require a greater annual expenditure than that for air or water pollution control. Unit reclamation costs for the thick deposits are expected to be less than in other parts of the Nation. These costs are part of the production costs and should be borne by the ultimate consumer.

635. Peters, T. H.
1978. Inco Metals reclamation program. In Proc., 80th Annu. Meet., Canadian Inst. of Mining and Metallurgy [April 1978, Vancouver, B.C.]. 9 p. Can. Inst. of Mining and Metall., Vancouver, B.C.

The paper reviews the history of Inco Metals' reclamation program which began in 1917 with the construction of Nickel Park. Revegetation techniques, species selection, seed mixtures, mulch, and fertilizer treatments are included. In 1974 a wildlife management plan for development of a wildlife management area on the reclamation site was implemented.

636. Peters, W. C., ed.
1970. Mining and ecology in the arid environment. Dep. Mining and Geol. Eng., Univ. Ariz., Tucson.

637. Pommerening, E.
1976. Revegetation of the Coeur d'Alene mining district. 17 p. [AMC Mining Cov., set No. 2: Environ. Controls 1 & 2, Denver, Colo., Sep. 26-29, 1976.] Am. Mining Congr., Washington, D.C.

The paper describes a major revegetation program which was begun in 1974 by the Bunker Hill Company in the mine-affected area of the Coeur d'Alene mining district in northern Idaho. Disturbances of two types are present within the district: tailings deposits from the concentrators and denuded mountain slopes. The original vegetation on the mountain slopes was destroyed by forest fires. Reforestation was prevented by high concentrations of SO_2 in gaseous emissions from the Bunker Hill Company's lead smelter and electrolytic zinc plant. The company's efforts aimed at establishing vegetation at the sites of the tailings ponds within the district are highlighted. These included soil tests, fertilization, irrigation, growth of trees and shrubs, and their planting.

638. Pommerening, E.
1977. Revegetation of the Coeur d'Alene mining district. Mining Congr. J. 63(3):20-23.

A major revegetation program was begun in 1974 by the Bunker Hill Co. in the mine-affected area of the Coeur d'Alene mining district in northern Idaho. Little research had been done on heavy metal mine and smelter disturbances in the West. Disturbances of two types are present within the district: tailings deposits from the concentrators and denuded mountain slopes. The original vegetation on the mountain slopes was destroyed by forest fires. Reforestation was prevented by high concentrations of SO_2 in gaseous emissions from Bunker Hill's lead smelter and electrolytic zinc plant. Greenhouse experiments were conducted to determine which species of grasses and legumes and which fertilizer application would produce the best ground cover.

639. Prather, J. G.
1973. Vegetative stabilization of reclaimed copper stamp-sands. M.S. thesis. Mich. Tech. Univ., Houghton. 117 p.

A study to develop methods for the vegetative stabilization of a reclaimed copper stamp-sand deposit was initiated during September of 1970. Initial efforts were directed at reducing the movement of surface sand and eliminating airborne dust. Approximately 30 herbaceous species plus 39 tree and shrub species have been planted on the study area. Surface stabilization treatments including fiber mulch and adhesive chemicals have successfully stabilized portions of the study area. Seedings of grasses and legumes in conjunction with the surface stabilizing agents have been less than satisfactory in developing a vegetative cover. However, the correct mixture of irrigation, organic matter additions, and fertilizer amendments in conjunction with site amelioration techniques will produce stands of vegetation resulting in stabilization of the deposit.

640. Reed, J. B.
1970. Phosphate companies succeed in surface mine reclamation. 2 p. USDA Soil Conserv. Serv., Soil Conserv. Mag. (April 1970). Washington, D.C.

641. Reeder, J. D., and W. A. Berg.
1977. Plant uptake of indigenous and fertilizer nitrogen from a cretaceous shale and clay mine spoils. J. Soil Sci. Soc. Am. 41(5):919-921.

642. Research Committee on Coal Mine Spoil Revegetation in Pennsylvania.
1971. A guide for revegetating bituminous strip-mine spoils in Pennsylvania. 46 p.

643. Reynolds, J. F., M. J. Civik, and N. E. Kelley.
1978. Reclamation at Anaconda's open pit uranium mine, New Mexico. Reclam. Rev. 1(1):9-17.

644. Richardson, B. Z., E. E. Farmer, R. W. Brown, and others.
1976. Rehabilitation on a surface mined area of eastern Montana. In Fort Union Cold Field Symposium. p. 247-265. Mont. Acad. Sci., Billings.

This paper provides a comprehensive discussion on revegetation research in eastern Montana. Various soil treatments (fertilizer, mulch, no fertilizer, no mulch, topdressing, and irrigation) were tested. Three different seed mixtures were used: (1) natives, (2) native introduced, and (3) introduced species only. Results show that top-dressed treatment produces acceptable stands. Wheatgrasses are dominant in the first and second year but may fall off in the third year. There is strong evidence that native grasses will respond favorably to rehabilitation inputs at Decker coal mine.

641. Roberts, J. R.
1974. Mining and reclamation in Kentucky. In Res. and Appl. Technol. Symp. on Mined-Land Reclam., 2nd, Coal and the Environ. Tech. Conf. [Louisville, Ky., Oct. 22-24, 1974.] p. 1-4. Natl. Coal Assoc., Washington, D.C.

Surface mining of coal and of sand, stone, gravel, clay fluorspar, rock asphalt, and any other commercially mined solid material regulations are discussed.

646. Rowell, M. J.
1977. Continued studies of soil improvement and revegetation of tailings sand slopes. Norwest Soil Research Ltd. for Environmental Research, Mongr. 1977-4, 156 p. Syncrude Canada Ltd.

Studies were continued in 1976 into the improvement of a 5-year-old revegetated area on a tailings sand dike by the implementation of different fertilizer programs. In June 1976 levels of available N, P, K, and S were adequate for plant growth. However, even where fertilizers were added levels of mineral N had dropped to low levels by September 1976. Plant top production early in the 1976 season was increased by application of nitrogen fertilizer during the previous August. Continued good growth throughout the summer only occurred when extra N, P, K, and S fertilizers were added in June 1976. The most efficient use of fertilizer occurred when nitrogen was added at a rate of about 80 kg/ha or less. At the higher fertilizer application rates there was a tendency for bromegrass to replace creeping red fescue as the dominant grass in the area. The accumulation of root tissues has occurred over the past 5 years to the extent that current root:shoot ratios vary from about 4:1 to 7:1. Erosion of the area was negligible in 1976.

647. Sedgley, E. F.
1974. Revegetation potential of western rangelands in the oil shale regions. In Second Research and Applied Technology Symp. on Mined-Land Reclamation Proc. [Louisville, Ky., Oct. 22-24]. p. 29-33. J. F. Boyer, ed. Natl. Coal Assoc., Washington, D.C.

648. Shetron, S. G., and R. Duffek.
1970. Establishing vegetation on iron mine tailings. J. Soil Water Conserv. 25(6):227-230.

649. Shetron, S. G., B. M. Hamil, M. F. Jurgensen, and others.
1977. Establishing vegetation on alkaline iron and copper tailings. Mich. Dep. Nat. Resour., Geol. Surv. Div., Rep. of Investigation 17, 14 p.

Large scale field plantings commenced in the fall of 1970 and spring of 1971 to determine the potential of fine-grained alkaline iron and copper mine mill wastes for the growth of vegetation. Lack of essential nutrients such as nitrogen necessitated development of a special fertilizer blend and application rates to compensate for deficiencies. Three applications the first year, two the second, and a spring topdress each year thereafter have proven satisfactory in maintaining adequate plant growth. Excessively high levels of micronutrients such as iron in the iron tailings have not hindered plant growth. However, the same management on copper tailings has resulted in low plant survival. Severe wind and water erosion of the materials made mulching necessary. In those areas subjected to severe wind erosion, surface mulching resulted in greater plant survival.

650. Smith, R. A. H., and A. D. Bradshaw.
1972. Stabilization of toxic mine wastes by the use of tolerant plant populations. Inst. of Mining and Metallurgy, Trans. 81:A230-A237.

651. Specht, R. L.
1975. The effect of fertilizers on sclerophyll (heath) vegetation--the problems of revegetation after sand-mining of high dunes. Search, Sci. Technol. Soc. 6(11/12):459-461.

652. Stucky, D. J., and T. S. Newman.
1977. Effect of dried anaerobically digested sewage sludge on yield and element accumulation in tall fescue and alfalfa. J. Environ. Qual. 6(3):271-278.

Two rates of dried anaerobically digested sewage sludge were used in a greenhouse pot study to determine the effect on yield, areal coverage, and element accumulation in "Ky-31" tall fescue and alfalfa grown during a 2-year growth period, on an agricultural soil and on acid strip-mine spoil. The initial pH of strip-mine spoil was approximately 3.5, and sludge additions of 314 and 627 metric tons/ha raised the pH to 5.5 and 6.0, respectively. Sludge applications of 314 and 627 metric tons/ha significantly increased yields of plants grown on agricultural soil. On strip-mine spoil, yields of tall fescue and alfalfa were significantly increased at the application rate of 627 metric tons/ha. In all treatments the yields of alfalfa were greater than that of tall fescue, although the areal coverage of fescue exceeded that of alfalfa. Increasing rates of sewage sludge decreased the amount of Mn, Zn, Ni, and Cd accumulated in tall fescue and alfalfa in strip-mine spoils. Copper accumulation was not affected by application rates.

653. Summer, R. M.
1978. Sand and gravel reclamation factors, Colorado County, Texas. Mining Eng. 30(1):45-47.

654. Tayki, S. K., M. H. Rowell, W. B. McGill, and others.
1977. Reclamation and vegetation of surface mined areas in the Athabasca tar sands. Environ. Res. Monogr. 1977-1, 170 p. Syncrude Canada Ltd.

One of the major environmental problems which arises with surface mining of the oil sands in the Fort McMurray-Fort MacKay area of Alberta is the permanent loss of the natural vegetation and the drastic change in the soils that supported it. It has been estimated that with a production target of 1 million barrels of crude oil per day approximately 2,000 acres of land will have to be cleared every year. Most of the disturbed areas eventually must be vegetated again; these include the overburden piles and the tailings sand. In vegetating such areas several problems such as salinity, oil, low fertility, erosion, and unfavorable soil reaction must be contended with. There has been some success in the general vegetation program on the Great Canadian Oil Sands Ltd. lease, but the problems listed above still have to be studied and solutions for them found. The following research projects were undertaken to solve some of these problems.

655. Terwilliger, C., C. W. Cook, and P. L. Sims.
1974. Natural and artificial rehabilitation of disturbed sites in an oil shale area. In Surface rehabilitation of land disturbances resulting from oil shale development, executive summary. p. 17-25. C. W. Cook, ed. Colo. State Univ., Fort Collins, Environ. Resour. Cent., Infor. Series 11, 56 p.

656. Tresler, R. L.
1974. Strip mine reclamation in Wyoming. In Second Research and Applied Technology Symp. on Mined-Land Reclamation Proc. [Louisville, Ky., Oct. 22-24]. p. 22-28. Natl. Coal Assoc., Washington, D.C.

Various techniques being used in mine reclamation throughout Wyoming are discussed and key steps in revegetating are systematically presented.

657. USDA Soil Conservation Service.
1963. Guide for classifying and revegetating strip-mine spoil in Pennsylvania. 23 p. USDA Soil Conserv. Serv., Harrisburg, Penn.

658. Van Kekerix, L. K., R. W. Brown, and R. S. Johnston.
1979. The effect of mine spoil treatments on seedling water relations. USDA For. Serv. Res. Note INT-262, 17 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

659. Verma, T. R., K. L. Ludeke, and A. D. Day.
1977. Rehabilitation of copper mine tailing slopes using municipal sewage effluent. Hydrol. and Water Resour. in Ariz. and the Southwest 7:61-68.

660. Vivyurka, A. J.
1975. Rehabilitation of uranium mines tailings areas. Can. Mining J. 96(6):44-45.

661. Vories, K. C., and P. L. Sims.
1977. The plant information network: vol. I. A user's guide. p. 1-56. Western Energy and Land Use Team, Off. Biol. Serv., U.S. Fish and Wildlife Serv., Fort Collins, Colo.

662. Vories, K. C., and P. L. Sims.
1977. The plant information network: vol. II. Reclamation and PIN in northwestern Colorado. p. 57-108. Western Energy and Land Use Team, Off. Biol. Serv., U.S. Fish and Wildlife Serv., Fort Collins, Colo.

663. Vories, K. C., and P. L. Sims.
1977. The plant information network: vol. III. Reclamation and PIN in the Powder River Basin of Montana and Wyoming. p. 109-160. Western Energy and Land Use Team, Off. Biol. Serv., U.S. Fish and Wildlife Serv., Fort Collins, Colo.

664. Ward, R. T., W. Slauson, and R. L. Dix.
1974. The natural vegetation in the landscape of the Colorado oil shale region. In Surface rehabilitation of land disturbances resulting from oil shale development, executive summary. p. 9-17. C. W. Cook, ed. Colorado State Univ., Fort Collins, Environ. Resour. Cent., Infor. Series 11, 56 p.

665. Watkin, E. M., and J. E. Winch.
1973. Composed organic wastes, sewage sludges, and rock phosphate for amelioration of acid uranium mine tailings. In Proc., Int. Conf. on Land for Waste Management [Ottawa, Can., Oct. 1973]. p. 48-56.

666. Wells, E.
1969. Voluntary land reclamation in the Florida phosphate industry. Proc. Mining Environ. Conf. [Rolla, Mo., Apr. 16-18]. p. 110-115. Univ. Missouri, Rolla.

Work done by phosphate mining industry in Florida in reclaiming the land after mining out of phosphate ore is reported.

667. Western Miner.
1973. Summary of vegetation programme on lead-zinc tailings pond. Western Miner 46(8):32-33.

668. Wienke, C. L., and D. R. Dreesen.
1977. Ecological investigation of rehabilitation of uranium mill tailings of the southwestern United States. Los Alamos Sci. Lab. Progr. Rep. W7405, 77 p.

669. Willard, B. E.
1979. Plant sociology of alpine tundra of Trail Ridge, Rocky Mtn. Nat'l. Park, Colorado. Colo. Sch. Mines, Monograph, 119 p. [ISSN0010-1753.]

670. Williams, B. D., and P. E. Packer.
1979. Sewage sludge and other materials as amendments for revegetation of spent oil shale. In Proc., Symp. on Rehabilitation of Drastically Disturbed Land [Philadelphia, Penn., March 1977]. p. 353-358.

If large-scale production of oil from these western shales becomes a reality, and it almost certainly will, vast quantities of spent shale will be produced and will require disposal. Stabilization of these disposal sites to control erosion and to prevent or to reduce degradation of water quality is a necessary land management objective. Some research has already been done, with varying degrees of success, to develop measures for revegetating spent shale. Little has been done, however, to improve the properties of this spent shale for plant growth by using as amendments readily available, organic waste materials from sources other than mined areas. Use of such amendments might help the establishment of vegetation on spent shale as well as provide a profitable way to dispose of these organic wastes. For these reasons, bioassay studies were undertaken to determine the growth responses of a salt-tolerant plant, tall wheatgrass (*Agropyron elongatum*), grown in spent shale treated with various combinations of leaching, fertilizer, and organic amendments. Results of these studies show that organic waste amendments effectively enhance plant growth in spent oil shale and that some amendments are significantly more effective than others.

671. Wiseman, T.
1978. Hitting pay dirt with pine seeds: strip mines reforested. Mining Congr. J. 64:59-60.

This article discusses the benefits of direct seeding of steep/rocky strip-mined land with pine seed that has been treated with effective bird and rodent repellents. In many places where soil conditions are good for pine tree establishment, pines cannot be planted (due to topography, etc.). These are prime areas for direct, aerial seedings. Results can be quite good.

672. Zuck, R. H., and L. F. Brown, eds.
1976. Proc., High Altitude Revegetation Workshop No. 2. Colo. State Univ., Environ. Resour. Cent., Infor. Series 21, 120 p.

Papers include such topics as: reclamation laws, training reclamation personnel, plant materials (collection of wildland seed, use of containerized seedlings, shrubs, and trees), establishment methods, etc.

M. Environmental Effects, Impacts, Baseline Data

Section M includes environmental impact statements, "state-of-the-art" publications, and those citations that provide baseline data on broad environmental effects of surface mining.

673. Ackerman, D. H.
1973. Environmental impact study: a tool for sound mineral development. Mining Congr. J. 59(12):16-22.

As a result of some 8 years of exploratory work, the American Metal Climax Co. has ascertained that a copper-molybdenum deposit located in northwest Wyoming, near an old mining camp of Kiroin has sufficient Cu-Mo mineralization to warrant its consideration as an open pit mine. Paper discusses the scope of an environmental impact study, which will have to be completed with cooperation of local authorities before a final decision is taken. Some more significant elements of the study are: reclamation of the vegetation at the altitude of open pit from 8,000 to 11,000 ft; waste and tailings disposal in a high, narrow valley; water pollution by mine drainage and ore treatment plant; housing, etc.

674. Atomic Energy Commission.
1972. Leasing of AEC controlled uranium bearing lands, Colorado, Utah, New Mexico. 203 p. Atomic Energy Comm., Washington, D.C. [Available NTIS as EIS-CO-72-5340-F.]

The statement has been prepared in support of the AEC's administrative action to lease about 25,000 acres of uranium bearing lands. With strict enforcement of stipulations, the mining operations are expected to have a minimal impact on the environment.

675. Automation Industries, Inc.
1977. Energy/Environment II. Proceedings of Second National Conference on the Interagency R and D Program [Washington, D.C., June 6-7]. 514 p. Automation Industries, Inc., Silver Springs, Md. [Available NTIS as PB-277 917/1ST.]

All papers presented at this conference, along with discussion from question and answer periods, are included in the text. Topics discussed include the following: fuel processing; utility and industrial power; extraction and beneficiation; integrated technology assessment; health effects; atmospheric transport and fate; measurement and monitoring; ecological effects.

676. Box, T. W.
1973. The energy crisis and the fate of strip mine lands. Utah Sci. 35(4):117-120.

677. Cammarota, V. A., Jr.
1978. Zinc. 33 p. U.S. Bur. Mines, Washington, D.C. [Available NTIS as PB-283 732/6ST.]

The zinc industry is reviewed in terms of structure, organization, and geographic distribution. The geology of zinc deposits, resources, and mining and smelting of zinc are briefly described. The economic and environmental factors associated with zinc extraction are discussed. The report gives an overview of the uses of zinc in transportation, construction, electrical equipment, machinery, paint, chemicals, and rubber products, and forecasts the use of zinc to the year 2000. The U.S. demand in 2000 is forecast to be about 2.2 million tons, representing an annual growth rate of 2.0 percent and 9.1 million tons for the rest of the world at an annual growth of 2.1 percent. While U.S. mine production is expected to reach 800,000 tons, the nation will continue to rely on imports for a significant portion of its supply. Reserves were considered sufficient to supply anticipated world demand for primary zinc.

678. Clark, D. A.
1974. State-of-the-art: uranium mining, milling and refining industry. 123 p. Robert S. Kerr Environ. Res. Lab., Ada, Okla. [Available NTIS as PB-235 557/6.]

679. Colorado University.
1971. An interdisciplinary study of transport and biological effects of molybdenum in the environment. 133 p. Colo. Univ., Boulder. [Available NTIS as PB-222 821/1.]

The purpose of the research effort is to examine the release and transport of molybdenum and its subsequent impact on man and his environment. This study has particular relevance to Denver and the surrounding mountainous and agricultural areas which are target areas for abnormally high levels of molybdenum in streams draining the mountainous area to the west of Denver. The study consists of an interdisciplinary effort which involves: (1) determining the sources of the molybdenum in surface waters, (2) determining the rates and modes of transport, (3) determining the targets, (4) determining the biological cycling, (5) developing analytical tools, (6) examining the biological effects particularly with regard to calcium transport and energy transduction, (7) examining the potential economic ramifications of the study, (8) studying various aspects of the public perception of who the public holds responsible and how willing the public is to participate in the solution of a possibly hazardous situation.

680. Cook, C. W.
1974. Surface rehabilitation of land disturbances resulting from oil shale development. Final rep., phase I. 255 p. Colo. State Univ., Fort Collins.

681. Cook, C. W., R. C. Austin, V. W. Brown, and others.
1973. Study team on environmental problems associated with fuel materials. 106 p. Mass. Inst. Tech. Press, Cambridge, Mass.

682. Conkle, N., V. Ellzey, and K. Murthy.
1974. Environmental considerations for oil shale development. Battelle Columbus Labs, Ohio.

Results of a preliminary literature study of the environmental considerations in the development of an environmentally acceptable oil shale industry are presented. The following seven different areas are included in the study: oil shale deposits; in-situ retorting; ex-situ retorting; retorted shale disposal; mining, handling, and pretreatment processes; other environmental considerations; and product treatment and usage. Research and development needs required to eliminate inadequacies in the data base necessary to evaluate potential environmental problems are noted. The report provides an overview of the anticipated oil shale industry, including the magnitude of the resources available and the likely technical and environmental problems to be encountered. Specific technologies likely to be employed in the mining, oil extraction, and on-site upgrading process are also identified.

683. Conkle, N., V. Ellzey, and K. Murthy.
1974. Environmental considerations for oil shale development. Final report, Jan.-May 1974. 133 p. Battelle Columbus Labs, Ohio. [Available NTIS as PB-241 942.]

An overview is provided of the anticipated oil shale industry, including the magnitude of the resources available and the likely technical environmental problems to be encountered. Specific technologies likely to be employed in the mining, oil extraction, and on-site upgrading processes are also identified. The status of development of these technologies and their potential economic, resource, and environmental impacts upon the oil shale resource regions and the nation as a whole are also described.

684. Crawford, K. W., and others.
1977. A preliminary assessment of the environmental impacts from oil shale developments. 174 p. TRW Environ. Eng. Div., Redondo Beach, Calif. [Available NTIS as PB-272 283.]

685. Davis, G.
1978. Oil shale. In Reclamation of drastically disturbed lands. p. 609-618. F. W. Schaller and P. Sutton, eds. Agron. Soc. Am., Crop Sci. Soc. Am., Soil Sci. Soc. Am., Madison, Wis.

This paper gives a summary of oil shale: what it is, where it is found, how it is mined, and problems in oil shale development. Also included is a section on reclamation of oil shale. Stability, hydrology, and revegetation of spent oil shale are discussed.

686. Dawson, A. D.
1974. Earth removal and environmental protection. Environ. Affairs 3:166-187.

687. Dinneen, G. U., and G. L. Cook.
1975. Oil shale and the energy crisis. In Perspectives on energy. p. 377-385. L. C. Ruedisili and M. W. Firebaugh, eds. Oxford Univ. Press, London. 527 p.

688. Doherty, F. J.
1974. Environmental factors involved in applying for a zoning permit to extract sand and gravel--a case history. 13 p. Natl. Sand and Gravel Assoc., Washington, D.C.

689. Dole, H. T. Beard, J. Bredehoeft, and others.
1974. Report of the committee on environment and public planning. Newsl. Geol. Soc. Am. Suppl. 9(4):1-8.

A review on technology and environmental effects of developing oil shale in the Green River formation.

690. Donnelly, W. H.
1974. Impact of energy shortages on U.S. environmental standards. 52 p. Library of Congress, Washington, D.C. [Microfiche number 74-78.]

The recent energy shortages in the United States have created numerous problems, including environmental ones. These environmental issues involve extraction of fuels from nature, their use, and the siting of large energy facilities. All have generated controversy, and the present situation has caused many to question the desirability of controls to protect the environment from effects of supplying and using fuels and energy. The report examines energy variances and NEFA effects of the energy shortage on air quality, nuclear power, power plant siting, outer continental shelf development, and surface mining of coal and oil shale.

691. Dorset, P., D. Myers, and T. Parker.
1977. Advanced fossil fuel and the environment: an executive report. U.S. Environ. Protec. Agency, Off. Res. and Develop., EPA 60019-77-013. Cincinnati, Ohio.

692. Ellis, J. E., and W. J. Parton.
1978. Impact of strip-mine reclamation practices: a simulation study. 329 p. Western Energy and Land Use Team, Off. Biol. Serv., U.S. Fish and Wildlife Serv., Fort Collins, Colo.

693. Engineering and Mining Journal.
1970. A national western mining conference--its uranium, pollution, and technology. Eng. and Mining J. 171(4):74-75.

694. Falk, M. R., M. D. Miller, and S. M. Kostivk.
1973. Biological effects of mining wastes in the Northwest Territories. Environ. Can., Fish. and Marine Serv., Tech. Rep. Series CEN/T-73-10.

Studies to determine the effect of mine wastes on aquatic biota are discussed in this paper. Water quality, effluent toxicity, metal contamination, invertebrates, fish, and benthos diversity were assessed at each study site.

695. Frazier, N. A.
1976. Production and processing of U.S. tar sands: an environmental assessment, final report. 92 p. Battelle Columbus Labs, Ohio. [Available NTIS as PB-266 266/6GA.]

696. Gage, S. J.
1975. A federal energy/environmental research and developmental program. In Energy Technology II: Second Energy Technology Conference Proc. [Washington, D.C., May 12-14.] p. 242-270. T. F. P. Sullivan, ed. Government Institutes, Inc., Washington, D.C. 344 p.

697. Gage, S. J.
1977. Appalachian mineral resource development: environmental factors. 17 p. Mitre Corporation, McKean, Va. [Available NTIS as PB-274 107/2GA.]

698. Garofalo, D., and F. J. Wobber.
1974. Aerial-photographic analysis of the environmental impact of clay mining in New Jersey. Photogrammetria 30(1):1-19.

Black-and-white, color, and color-infrared photography at 1:20,000 scale or larger provide useful data for monitoring the environmental effects of surface mining as demonstrated, following study of surface clay mining. Investigations using high-altitude color and color-infrared photography at scales of 1:80,000 to 1:120,000 provide an efficient technique for inventorying large-surface mining operations or for rapid statewide mining studies.

699. Givens, B. M., and C. A. Boyd.
1976. Energy Research Information System, vol. 1, No. 1. 238 p. Old West Regional Commission, Billings, Mont. [Available NTIS as PB-276 851/3ST.]

The goal of the Energy Research Information System (ERIS) is to provide an inventory of energy-related programs and research activities from 1974 to the present in the States of Montana, Nebraska, North Dakota, South Dakota, and Wyoming. Areas of research covered include coal, reclamation, water resources, environmental impacts, socioeconomic impacts, energy conversion, mining methodology, petroleum, natural gas, oil shale, renewable energy resources, nuclear energy, energy conservation, and land use. Each project description lists title, investigator(s), research institution, sponsor, funding, time frame, location, a descriptive abstract of the research, and reports and/or publications generated by the research. All projects are indexed by location, personal names, organizations, and subject keywords. This report contains 300 project references.

700. Givens, B. M., and C. A. Boyd.
1976. Energy Research Information System, vol. 1, No. 2. 108 p. Old West Regional Commission, Billings, Mont. [Available NTIS as PB-276 852/1ST.]

Areas of research covered include coal, reclamation, water resources, environmental impacts, socioeconomic impacts, energy conversion, mining methodology, petroleum, natural gas, oil shale, renewable energy resources, nuclear energy, energy conservation, and land use. Each project description lists title, investigator(s), research institution, sponsor, funding, time frame, location, a descriptive abstract of the research, and reports and/or publications generated by the research. All projects are indexed by location, personal names, organizations, and subject keywords. This report contains 93 project references and is in addition to volume 1, No. 1 (portions of this document are not fully legible).

701. Givens, B. M., and C. A. Boyd.
1976. Energy Research Information System, vol. 1, No. 3. 126 p. Old West Regional Commission, Billings, Mont. [Available NTIS as PB-276 853/9ST.]

Areas of research covered include coal, reclamation, water resources, environmental impacts, socioeconomic impacts, energy conversion, mining methodology, petroleum, natural gas, oil shale, renewable energy resources, nuclear energy, energy conservation, and land use. Each project description lists title, investigator(s), research institution, sponsor, funding, time frame, location, a descriptive abstract of the research and reports and/or publications generated by the research. All projects are indexed by location, personal names, organizations, and subject keywords. This issue contains 146 project references and is in addition to volume 1, No. 1 and No. 2.

702. Givens, B. M., and C. A. Boyd.
1976. Energy Research Information System, vol. 1, No. 4. Cumulative indexes. 98 p. Old West Regional Commission, Billings, Mont. [Available NTIS as PB-276 854/7ST.]

This cumulative index includes a State location index, an organization index, and a subject keyword index incorporating the indexes from Energy Research Information System (ERIS), volume 1, Nos. 1, 2, and 3. This issue plus the first three ERIS reports comprise a set of 539 research project references for the States of the Old West Region--Montana, Nebraska, North Dakota, South Dakota, and Wyoming.

703. Hanson, W. C., and F. R. Meira, Jr.
1977. Long-term ecological effects of exposure to uranium. Los Alamos Sci. Lab. Progr. Rep. W7405-ENG, 34 p.

704. Hays, R. M.
1974. Environmental, economic, and social impacts of mining copper-nickel in northeastern Minnesota. 149 p. Dep. Civil and Mining Eng., Minn. Univ., Minneapolis. [Available NTIS as PB-204 466/3ST.]

The Culuth Gabbro Complex in northeastern Minnesota possibly contains a significant domestic copper resource and the Nation's largest nickel resource. Exploration has discovered large low-grade copper-nickel (Cu-Ni) deposits between Hyt Lakes and the Boundary Water Canoe Area. The mining and processing of Cu-Ni will have environmental, economic, and social impacts. The purpose of the study is to relate major environmental, economic, and social considerations to various aspects of Cu-Ni extraction. An open pit and two underground (block caving and open sloping with backfilling) models were developed to generate information on the impact of Cu-Ni extraction. Important considerations having environmental, economic, and social impacts during various aspects of Cu-Ni extraction are identified and defined. These aspects are exploration, development, mining, beneficiating, smelting, industrial, energy, climatic, resource, water, air emission, waste disposal, employee, tax and royalty, transporation, and community considerations.

705. Hendricks, D. W., and H. C. Ward.
1976. Environmental analysis of an oil shale industry in the upper Colorado region. In Oil shale. p. 215-234. T. F. Yen and G. V. Chilingar, eds. American Elsevier Publishing Company, Inc., New York. 292 p.

706. Henry, C. D.
1976. Land resources inventory of lignite strip-mining areas, East Texas: an application of environmental geology. Univ. Texas, Austin, Bur. Econ. Geol., Geol. Circ. 76-2, 28 p.

707. Howe, C. W., and others.
1976. Integrated socioeconomic-hydrosalinity-air quality analysis of shale oil and coal development in Colorado. In EPA Conference on Environmental Modeling and Simulation Proc. [Cincinnati, Ohio, Apr. 19-22]. p. 34-35. W. R. Ott, ed. Booz-Allen Applied Research, Inc., Chicago, Ill. 861 p. [Available NTIS as PB-257 142/OGA.]

708. Hunkin, G. G.
1975. The environmental impact of solution mining for uranium. Mining Congr. J. 61(10):24-27.

Compared with most other mining systems, uranium solution mining has a negligible effect on such environmental factors as surface disturbance, interference with natural groundwater quality and distribution, and aerial discharge of radionuclides. Borehole mining by the in-situ leaching of uranium from naturally permeable deposits enables the economic exploitation of these reserves under current production-cost, selling-price conditions. Engineered well systems and controlled input/production flow rates, combined with full recirculation systems that maintain constant fluid volumes in the mineralized formations, result in

containment of leach solutions within the operating area. The very dilute leach solutions, compatible with natural groundwaters, ensure that no environmental damage results, even if a loss of control occurred. Virtual elimination of operator hazards, waste diposal, and land rehabilitation costs help in reducing overall costs. The reduction in the number of stages of processing results in substantial savings in energy, operating costs, labor requirements, capital, and lead times.

709. Ichiye, T.
1978. Deep Ocean Mining Environmental Study (DOMES). Mid-ocean aquaculture - benefits of deep ocean mining operation. Unpubl. ms. No. 30, 63 p. Natl. Oceanic and Atmospheric Admin., Seattle, Wash. [Available NTIS as PB-284 744/0ST.]

The possibility of developing a midocean aquaculture in the vicinity of a deep ocean mining project is examined. The Deep Ocean Mining Operation (DOMO) will produce the vertical velocity comparable to the natural upwelling in the midocean. Actually DOMO is more efficient in bringing the bottom water to the surface, because in natural conditions the vertical eddy diffusivity sometimes counteracts upwelling in upward transport of the bottom water. Most marine biologists consider that the primary productivity of the ocean is mainly enhanced by nutrients brought near the surface from the bottom by upwelling or by other processes. Therefore, DOMO might be able to increase the primary productivity of the oceanic region which is rather barren in the natural conditions, if it is carried out with careful planning. Further investigation of the potentials for aquaculture in the DOMO area is proposed.

710. Information Systems Technical Laboratory, Federation of Rocky Mountain States, Inc.
1977. Natural resource geographic data bases for Montana and Wyoming. 78 p. U.S. Fish and Wildlife Serv., Biol. Serv. Prog., Fort Collins, Colo.

711. Janes, D. C., and others.
1977. Monitoring environmental impacts of the coal and oil shale industries: research and development needs. 207 p. Radian Corporation, Austin, Tex. [Available NTIS as PB-266-292/2GA.]

712. Jones, M. J., ed.
1975. Minerals and the environment. 103 p. Inst. of Mining and Metallurgy, London.

Forty-one papers presented at this symposium discuss various methods by which environmental damage in mining can be substantially reduced, if not entirely eliminated. Preference is given to papers that indicate how such damage could be avoided rather than those that merely describe environmental damage that had already taken place. The subjects discussed include: environmental aspects of the North American mining industry; surveillance of mining operations by satellite (ERTS-1); water reuse in Canadian ore-concentration plants; pollution control and upgrading of mineral finds with bitumen; open cast coal mining; working, restoration, and reclamation; ecological approach to mining waste revegetation; environmental control in iron ore sintering; some practical aspects of dust control in coal mining; and mining subsidence and the environment. Selected articles are indexed separately.

713. Jumars, P. A.
1977. Deep Ocean Mining Environmental Study (DOMES). Potential environmental impact of deep-sea manganese nodule mining: community analysis and prediction. Unpubl. ms. No. 13, 54 p. Natl. Oceanic and Atmospheric Admin., Seattle, Wash. [Available NTIS as PB-283 152/7ST.]

Much of the progress in this study is summarized in the two attached manuscripts. The first develops spatial autocorrelative methods for ecological application, and the second establishes their relevance to analysis and descriptions of deep-sea benthic (baseline) data. The initial impact and the rate and degree of recovery depend on the spatial and temporal scales both of the disturbance and of the segment of the community that has not been disturbed. The answers change not only between communities with differing species compositions but also within the same community as the pattern and extent of the disturbed area changes. None of these questions can be adequately answered before monitoring of mining effects begins.

714. Kallus, M. F.
1975. Environmental aspects of uranium mining and milling in South Texas. 7 p. Surveillance and Anal. Div., Environ. Protec. Agency, Houston, Tex. [Available NTIS as PB-266-318/5GA.]

Recent investigations of uranium mining and milling operations in the Grants Mineral Belt of New Mexico found serious environmental problems to be associated with these activities. The purpose of this investigation was to determine whether or not similar problems existed in the South Texas uranium belt. The investigation showed that these problems did not exist. Activities included in the investigation were (1) a literature search to gather background information; (2) a search of the files of State environmental regulatory agencies to assemble pertinent data; (3) an aerial and surface reconnaissance of the area involved; and (4) discussions with involved persons in both the governmental and private sectors.

715. Larson, W. C.
1978. Uranium in situ leach mining in the United States. U.S. Bur. Mines Infor. Circ. 8777, 68 p. Washington, D.C.

716. Lawver, J. E., W. O. McClintock, and R. E. Snow.
1978. Beneficiation of phosphate rock--a state-of-the-art review. Min. Sci. Eng. 1(4):278-294.

This paper presents the production statistics, the location, ore type, and process methods of beneficiation used for the major phosphate deposits of the world. A new process under development by International Minerals and Chemical Corporation for beneficiating sedimentary dolomitic phosphate is briefly described. Beneficiation technology of phosphate ore has progressed considerably in the past decade, and the industry has developed methods of processing deposits as low as 10 to 15 percent bone phosphate of lime. The major problems facing the industry are the development of new economic mining methods for handling deep deposits, and the constantly increasing burden of regulatory agencies to meet rigorous environmental standards and eventually to process ore with zero water discharge from the beneficiation plant.

717. Li, T. M.
1978. Southeastern Idaho phosphate mining: how an environmental impact statement distorts growth plans. Mining Eng. 30(1):25-28.

718. McDonald, A.
1974. Shale oil: an environmental critique. Center for Science in the Public Interest, Washington, D.C. Oil Series III, 62 p.

719. Masuda, J., and T. Yamamoto.
1971. Studies on environmental contamination by uranium, 2. Absorption of uranium on soil and its desorption. J. Rad. Res. 12:94-99.

720. Merritt, R. C.
1972. Environment. Mining Eng. 24(2):97-101.

Pollution problems troubling the metallurgical industry are presented. With the introduction of new SO_2 emission standards it became apparent that existing technology available to nonferrous smelters cannot achieve 94 percent control with the government's estimate of $108 million. The copper industry alone would achieve only 85 percent control at a cost approaching $600 million. It is concluded that without huge capital investments for new production technology, the pollution standards cannot be met by nonferrous smelters. Although the paper deals primarily with SO_2 emissions, several case histories present facts on acid mine drainage water treatment, metal recovery processes, tailings stabilization, and metals reclamation from refuse.

721. Meyers, D. L.
1977. Environmental impacts of oil shale development. 34 p. Stanford Research Institute, Menlo Park, Calif. [Available NTIS as PB-276 617/8WN.]

722. Mining Engineering.
1971. Mineral industry vs. ecology. Mining Eng. 23(8):51-60.

All aspects of human environment effectively connected with the mineral industry are discussed. Pneumoconiosis as a result of coal mining is under control in a modern mine, however it is still a threat as is the case with silicosis in metal mines. Instrumentation protecting people from these hazards is described. Basic ways in which surface mining disturbs the land are spoil banks, high walls, toxic soil, and waste disposal. Results of recent Kennecott tailings stabilization tests are presented. Water pollution problems are in urgent need for attention, particularly in metal industries. Magnetic agglomeration seems to be a promising method for classification and separation of metallics in solid wastes, as well as in treatment of steel industry waste waters. Air pollution control measures are also presented.

723. Montana Department of State Lands.
1977. Bentonite mining related problems in the northwestern states. 94 p. Mont. Dep. state Lands, Helena.

724. Narayan, K., and P. J. Rand.
1977. Environmental considerations in uranium solution mining. Am. Inst. of Mining, Metallurgical and Petroleum Eng., Soc. Mining Eng., Trans. 262(2):117-119.

725. National Academy of Sciences.
1975. Mineral resources and the environment. 348 p. Natl. Acad. Sci., Washington, D.C.

This report studies the general issues involved with the continued availability and efficient use of our minerals and mineral resources: demand, supply, technology, and environmental impact of production. Among the topics discussed are technological opportunities in the materials cycle to offset shortages; a conservation ethic with regard to our resources; capital, manpower, and time constraints on technology; world resources of petroleum and natural gas, discovered reserves and undiscovered recoverable resources; production of copper; environmental effects of coal production and use; mine safety and health; effects of sulfur pollutants on the public health; evaluation of demand projections; methods for estimating minerals resources and reserves.

726. Nerkervis, R. J., and J. B. Hallowell.
1976. Metals mining and milling process profiles with environmental aspects. 318 p. Battelle Columbus Labs, Ohio. [Available NTIS as PB-256 394/8ST.]

The report describes the environmental aspects of metals mining and milling (concentration operations in the U.S.). The metals include Al, So, Be, Cu, Au, Fe, Pb, Zn, Hg, Mo, Ni, Pt, the rare earth metals, Ag, Ti, W, U, and V. The types of environmental impacts associated with operations from mining through production of concentrate are described in general terms. The number and locations of plants, the names of producing companies, production levels, and other characterisitics of the industry are presented. Each unit process is described in terms of function, input materials, operating conditions, utilities and energy use, and waste streams. The descriptions of unit processes identify waste streams in terms of emissions to the air, water effluents, and solid wastes disposed to the land. The approximately 185 unit operations described include mining, dredging, crushing, flotation, leaching, sintering, and nodulizing. The most common waste streams are dusts from mining and crushing operations, liquid streams from mine drainage, flotation operations, tailings ponds, and leach operations.

727. Newport, B. D., and J. E. Moyer.
1974. State-of-the-art: sand and gravel industry. 46 p. Robert S. Kerr Environ. Res. Lab., Ada, Okla. [Available NTIS as PB-236 147/5ST.]

An overview is presented of the sand and gravel industry in the United States and its relationship to the environment. The fate and effects of sediment generated by this surface mining activity on the benthic, planktonic, and fish communities of waterways are discussed in detail. Problems of the sand and gravel industry, types of operations, status of current treatment technology, and legislation affecting the industry are reviewed.

728. Nuclear Regulatory Commission.
1977. Bear Creek Project (Converse County, Wyoming). 470 p. Draft environmental statement. Nuclear Regulatory Comm., Washington, D.C. [Available NTIS as NUREG-0129.]

The Bear Creek Project consists of certain mining and milling operations involving uranium ore deposits located in Converse County, Wyo. Mining of uranium from six known ore bodies will take place over a period of 10 years (estimated); a mill with a nominal capacity of 1,000 tons per day of ore will be constructed and operated as long as ore is available. The waste material (tailings) from the mill, also produced at a rate of about 1,000 tons per day, will be stored on-site in an impoundment. The project would convert about 2,700 acres from grazing use to mining and milling activities for a period of about 10 years. Mining activities would disturb (and remove vegetation from) a total of about 1,600 acres but, because of ongoing reclamation efforts, maximum acreage disturbed at any one time would be about 1,000 acres, with the average about 650 acres. An estimated 185 acres of highways and water remaining after reclamation would be lost to agricultural production. The milling activities would disturb about 430 acres; 330 of these would be reclaimed after operations cease, but the 100-acre tailings area must be considered unavailable for further productive use. Water will be removed from aquifers at about 1,000 gal/min (range 600 to 2,000 gal/min) by mine dewatering and mill operations. Long-term effects on groundwater are expected to be minor. Surface water will not be affected by normal operations. There will be no discharge of liquid or solid effluents from the mill. Discharges to air will be small and the effects negligible. The total dose rate to the bone is 1.1 mrem/y, and the whole-body-dose rate is computed to be 0.04 mrem/y.

729. Nuclear Regulatory Commission.
1977. Bear Creek Project, final environmental statement. 472 p. Nuclear Regulatory Comm., Washington, D.C. [Available NTIS as DOCKET-408452-1.]

The Bear Creek Project consists of certain mining and milling operations involving uranium ore deposits located in Converse County, Wyoming. Mining of uranium from nine known ore bodies will take place over a period of 10 years (estimated); a mill with a nominal capacity of 1,000 tons per day of ore will be constructed and operated as long as ore is available. The waste material (tailings) from the mill, also produced at a rate of about 1,000 tons per day, will be stored on-site in an impoundment. Environmental impacts and adverse effects are summarized.

730. Nuclear Regulatory Commission.
1977. Draft environment statement related to operation of Moab uranium mill (Grand County, Utah). 135 p. Nuclear Regulatory Comm., Washington, D.C. [Available NTIS as DOCKET-403453-1.]

This draft environmental impact statement was prepared by the staff of the Nuclear Regulatory Commission and issued by the Commission's Office of Nuclear Material Safety and Safeguards. The proposed action is the continuation of Source Material License SUA-917 issued to Atlas Corporation for the operation of the Atlas Uranium Mill in Grand County, Utah, near Moab (Docket No. 40-3452). This authorizes a 600-ton (450-t) per day acid leach circuit (for recovery of vanadium as well as uranium) and a 600-ton (450-t) per day alkaline leach circuit (for other ores, including copper-bearing ores).

731. Nuclear Regulatory Commission.
1977. Sweetwater Uranium Project; draft environmental statement. 197 p. Nuclear Regulatory Comm., Washington, D.C. [Available NTIS as DOCKET-408 584-1.]

The proposed action is the issuance of a Source Material License to Minerals Exploration Company for the construction and operation of the proposed Sweetwater Uranium Mill with a nominal capacity of 3,000 tons (2.7×10^6 kg) per day of uranium ore in Wyoming. The applicant proposes also to construct a heap-leaching and resin ion-exchange facility to extract uranium from low-grade ores and mine water. Impacts to the area due to the operation of the Sweetwater Uranium Mine/Mill Project will result in: alterations of up to 2,200 acres by the mill, mine pit area, and roads, and about 3,450 acres of Battle Spring Flat to be inundated by mine dewatering operations; increase in the existing background radiation levels; socioeconomic effects on Rawlins and other nearby areas; and tailings from the mill will be produced at a

rate of about 3,000 tons ($2.7x10^6$ kg) per day and will be stored on-site in a lined impoundment. Conditions for the issuance of the license are given.

732. Nuclear Regulatory Commission.
1978. Draft environmental statement related to the United Nuclear Corporation Morton Ranch, Wyoming uranium mill. 206 p. Nuclear Regulatory Comm., Washington, D.C. [Available NTIS as NUREG-0439.]

733. Nuclear Regulatory Commission.
1978. Draft environmental statement related to operation of Wyoming Mineral Corporation Irigary solution mining project. 180 p. Nuclear Regulatory Comm., Washington, D.C. [Available NTIS as NUREG-03999.]

734. Radcliff Materials.
1972. A study of the effects of gravel dredging on the upper Alabama River near Parkers Island, Montgomery and Elmore Counties, AL. 26 p. Radcliff Materials, Mobile, Ala.

735. Radian Corporation.
1975. A western regional energy development study: primary environmental impacts, vol. II. 771 p. Radian Corp., Austin, Tex. [Available NTIS as PB-246 265/3ST.]

The report examines the primary environmental impacts of 38 energy resource development scenarios: the air and water emissions, solid waste, and land requirements of a plant or process. Projected ground level ambient concentrations of pollutants are compared with Federal and State standards. Scenarios include all aspects of development: extraction, conversion, and transportation to the point of end use.

736. Rajaram, V., T. A. Kauppila, and R. L. Bolmer.
1978. Oil shale mining and the environment. Mining Eng. 30(4):360-363.

Experimental mining of oil shale, to date, has been conducted only in the shallow Mahogany zone and has utilized only the room and pillar mining method. The U.S. Bureau of Mines is planning a demonstration mine in the deep, thick oil shale deposits in Colorado. This paper describes the four mining concepts that are planned for demonstration and the interrelationship of these concepts and the environment. The environmental aspects of oil shale development are also discussed.

737. Rattien, S., and D. Eaton.
1976. Review of technological, economic, environmental, and institutional issues. In Annu. Rev. of Energy. p. 183-212. Jack M. Hollander, ed. Annual Reviews, Inc., Palo Alto, Calif.

Technological, economic, environmental, and institutional issues relating to the development of a commercial oil shale industry are reviewed. It is concluded that a commercial shale oil industry is feasible from a resource and technology perspective. Although there are unanswered questions about water supplies and the environmental impact of a developing shale oil industry, the chief uncertainty is economic. The outlook for prompt and sizable production of shale oil is uncertain in the absence of Federal intervention.

738. Reck, R. O.
1971. The regional economic and environmental impacts of the uranium mining and milling industry. Ph.D. diss. Univ. Maryland, Baltimore. 204 p. [Diss. Abst. Int. 36/06-A:2891.]

739. Reed, A. K.
1976. Assessment of environmental aspects of uranium mining and milling, final report. 59 p. Battelle Columbus Labs, Ohio. [Available NTIS as PB-266-413-4GA.]

This research program was initiated with the basic objective of making a preliminary assessment of the potential environmental impacts associated with the mining and milling of domestic uranium ores. All forms of pollution except radiation were considered. The program included a review of the characteristics and locations of domestic uranium ore reserves and a review of the conventional methods for mining and milling these ores. Potential environmental impacts associated with the entire cycle from exploration and mining to recovery and production of yellowcake are identified and discussed. Land reclamation aspects are also discussed. The methods currently used for production of yellowcake were divided into four categories: open pit mining-acid leach process, underground mining-acid leach process, underground mining-alkaline leach process, and in-situ mining. These are discussed from the standpoint of typical active mills that were visited during the program. Flowsheets showing specific environmental impacts for each category are provided.

740. Roels, O. A.
1974. Environmental impact of deep ocean mining. Mining Congr. J. 60(8):34-37.

Discovery of extensive deposits of manganese nodules on the deep ocean floor in many areas of the world's oceans has led to serious studies of the technical and economic feasibility of mining these nodules to extract copper, cobalt, and nickel. The most likely environmental effects of mining manganese nodules are: destruction of the benthic organisms and their habitats in the path of the mining operation; stirring up of sedimentary material as the mining implement sweeps the ocean floor; and introduction of sedimentary material, associated bottom organisms, and bottom water into various layers of the water column, including in some cases, surface water. From a 3-year study of those and related effects it appears that the environmental impact of deep-sea mining will probably be small, provided adequate precautions are taken during the mining operation. Our information to date is incomplete, however; a time series approach is required to establish the condition of the mining site before, during, and after the mining operations to document the change induced by mining and its reversibility.

741. Roels, O. A., A. F. Amos, O. R. Anderson, and others.
1973. The environmental impact of deep-sea mining. 186 p. Natl. Oceanic and Atmospheric Admin., Boulder, Colo. [Available NTIS as COM-74-50 489/5.]

The report gives a literature review of the known physical, chemical, and biological properties of the sea floor and the water column in the areas of the Pacific Ocean where manganese-nodule deposits of interest to the mining industry occur. The report contains the results of a baseline study of the physical, chemical, and biological characteristics of a manganese-nodule province on the Bermuda Rise in the Atlantic Ocean and of a potentially valuable manganese-nodule mining area in the eastern equatorial Pacific. The results of monitoring of a continuous-line bucket dredge manganese-nodule mining test in the Pacific Ocean are also reported. A detailed plan of work for a 3-year period to ensure the environmental safety of deep-sea mining is outlined.

742. Roels, O. A.
1974. Environmental impact of manganese nodule mining. Colloq. Int. Sur. l'Exploit des Oceans, 2nd, Proc., Prepr. and Pap., Paris, France. Oct. 1-4, 1974. 7 p.

The processing and extractive metallurgy of manganese nodules at sea, and the discharge of waste materials resulting from this processing, could be far more dangerous unless adequate precautions are taken. To ensure the safe development of this resource, and to avoid costly and drawn out legal wrangling based on the unsubstantiated opinions of "experts" for opposite viewpoints, it is clearly necessary that an orderly procedure be followed and that all environmental factors related to deep-sea mining be well documented.

743. Ross, D.
1975. Overview: environmental baseline monitoring program, tracts U-A and U-B. Colo. Sch. Mines Quar. 70(4):239-244.

744. Ruedisili, L. C., and M. W. Firebaugh, eds.
1975. Perspectives on energy. 527 p. Oxford Univ. Press, London.

745. Shaine, B. A.
1977. Assessment of environmental penalties introduced by transportation access to Alaska mineral resources. In Vol. II: working papers, analysis of laws governing access across federal lands. Appendix "C", 11 p. Off. Tech. Assessment, Washington, D.C.

The conclusions of the Wilderness Society were that (1) public decision on providing transportation to interior and remote areas of Alaska should consider all the costs and benefits, (2) transportation system should not subsidize any commercial venture, (3) routes should be carefully studied and planned especially in regard to wildlife.

746. Shilling, R. W., and E. R. May.
1977. Case study of environmental impact: Flambeau Project. Mining Congr. J. 63(1):39-44.

After 15 years of exploration in northern Wisconsin, Bear Creek Mining Company, the exploration arm of Kennecott Copper Corporation, discovered in 1968 a medium-sized copper-rich massive sulfide ore body, now referred to as the Flambeau deposit. Production, under Flambeau Mining Corporation (FMC), a wholly owned subsidiary of Kennecott, was planned for the mid-1970's. Now a startup date is set for the close of this decade, following the preparation of a State-required environmental impact statement by the company, which is described here.

747. States, J. B.
1975. Quantitative baseline definition for terrestrial ecosystems at oil shale tract C-A. In Environmental Oil Shale Symposium Proc. [Oct. 9-10]. p. 135-141. J. H. Gary, ed. Colo. Sch. Mines, Quar. 70(4). 244 p.

748. States, J. B., and others.
1978. A systems approach to ecological baseline studies. 400 p. Ecology Consultants, Inc., Fort Collins, Colo.

749. Stoddart, D. R., C. W. Benson, and J. F. Peake.
1970. Ecological change and effects of phosphate mining on Assumption Island. Natl. Res. Counc., Pac. Sci. Board, Atoll Res. Bull. 136:121-145.

750. Synthetic Fuels.
1975. Review of current developments in oil shale technology, including geological, environmental, and processing reports and patents. Syn. Fuels 12(1):2.1-2.68.

751. Technological Review.
1974. Oil shale and the energy crisis. Technol. Rev. 76:3.

A description is given of the oil shale deposits in the Green River formation in the United States with information on quantities of oil in place and analyses of the shale and its organic matter. Various techniques of recovering the crude oil are described and illustrated and refining methods discussed; the environmental impact of the industry and the economics are examined. A 100,000 barrel per day plant may cost $300 to $500 million, but the investment may become attractive when the price of crude reaches $4 per barrel.

752. Tibbs, N. H.
1977. In situ leaching of uranium. In Proc., Third Annual UMR-MEC Conf. on Energy: Energy crisis, an evaluation of our resource potential. J. D. Morgan, ed. Western Periodicals Co., North Hollywood, Calif.

In-situ leaching is a relatively new production method for uranium with several advantages. It will contribute an increasing portion of uranium supply as production turns to deposits inaccessible to conventional mining methods.

753. Tibbs, N. H., D. L. Rath, and T. K. Donovan.
1978. Environmental effects of uranium exploration and mining. p. 71-78. Proc. of the Fourth Annu. UMR-DNR Conf. on Energy [Univ. Mo., Rolla, Oct. 11-13, 1977]. p. 71-78. Univ. Mo.-Rolla, Dep. Nat. Resour., Exten. Div.

An examination of current practices and suggestions for future operations are presented. The probable cost to the environment of uranium exploration and mining is compared to the environmental costs from other energy sources.

754. USDA Forest Service.
1978. Environmental statement; Diamond Creek Planning Unit, Caribou National Forest. USDA For. Serv., Intermt. Reg., Rep. (Adm) R4-75-15, 370 p. Ogden, Utah.

This report is a complete final environmental impact statement for the Diamond Creek Planning Unit and for lease applications and phosphate prospecting permit applications within that unit. It was prepared by the Forest Service in accordance with Section 102(2) (C) of Public Law 91-190.

755. USDA Forest Service.
1972. A mineral exploration proposal in the Mazatzal Wilderness. Tonto National Forest - Environmental Impact Statement. 47 p. USDA For. Serv., Southwest. Reg., Albuquerque, N.Mex. [Available NTIS as EIS-AZ-72-5355-D.]

The Forest Service has prepared a draft environmental statement for a mineral exploration proposal in the Mazatzal Wilderness. The environmental statement considers probable environmental effects or impacts of a proposal for mineral exploration in the Mazatzal Wilderness.

756. USDA Forest Service.
1972. Palzo Restoration Project. Vienna Ranger District, Shawnee National Forest, Williamson County, Ill., E.I.S. 77 p. USDA For. Serv., East. Reg., Milwaukee, Wis. [Available NTIS as PB-207 061-D.]

The proposed project will attempt to utilize treated municipal waste to reclaim abandoned strip-mined land that is presently causing severe water pollution problems. Counties affected in Illinois include Williamson, Saline, and Gallatin. Adverse environmental effects that cannot be avoided may include slight increases in concentrations of cadmium, chromium, nickel, and nitrates in the runoff.

757. U.S. Department of the Interior.
1973. Final environmental statement for the prototype oil shale leasing program, vol. I. Regional impacts of oil shale development. 446 p. U.S. Dep. Interior, Washington, D.C.

758. U.S. Department of the Interior.
1973. Final environmental statement for the prototype oil shale leasing program, vol. III. Description of selected and potential environmental impacts. 697 p. U.S. Dep. Interior, Washington, D.C.

759. U.S. Department of the Interior.
1971. Prototype oil shale leasing program for the States of Colorado, Utah and Wyoming. [Specific States are in closing Impact Statement.] U.S. Dep. Interior, Washington, D.C. [Available NTIS as PB-203-318F.]

Effects of oil shale resource development on land and water use, wildlife of area.

760. U.S. Department of the Interior.
1967. Surface mining and our environment. A special report to the Nation. 124 p. U.S. Dep. Interior, Washington, D.C.

761. U.S. Department of the Interior.
1976. Navajo-Exxon uranium development: draft environmental impact statement. Planning Support Group, U.S. Dep. Interior, Bur. Indian Affairs, Billings, Mont.

762. U.S. Department of the Interior.
1977. Draft environmental impact statement. Vekol Hills Project, Papago Indian Reservation, Pinal County, Arizona. 200 p. U.S. Dep. Interior, Bur. Indian Affairs, Phoenix, Ariz.

763. U.S. Department of the Interior.
1971. Preference right phosphate lease application within the Los Padres National Forest, Ventura County, Calif. 39 p. Environ. Impact Statement. U.S. Dep. Interior, Bur. Land Manage., Washington, D.C. [Available NTIS as PB-200-775-D.]

The proposed action under consideration is the issuance of a preference right lease covering 2,434 acres that would authorize the U.S. Gypsum Company to extract phosphate ore by the open-pit method and produce phosphate compounds and other marketable byproducts on site. The phosphate deposit lies about half-way up the slope between Sespe Creek and the crest of Pine Mountain ridge. The phosphate rich zone is known to lie near ground surface in a more or less continuous band, varying from 1,000 to 2,000 feet in width. That roughly parallels the ridge of Pine Mountain for a distance of about 5 miles. The company proposes that a two-lane, black-topped entrance road, capable of handling 25-ton trucks would be built up Chorro Grande Canyon to the mine and processing plant. The company proposes to strip off the overburden (waste rock) and mine the ore by open-pit methods. A processing plant would be built adjacent to the mine site. A total of 1,152,000 gallons of water per 24-hour period would be drawn from a well approximately 940 ft deep. Considerable electric power will be needed. This could be supplied either from local power lines or from diesel or natural-gas powered generators on site. A transmission line 14 miles long would be needed to use existing power. Currently there are an estimated 60 to 70 California condors in existence and this bird is on the list of endangered species. The Los Padres National Forest is the hub of their range, containing all currently known nesting sites and having considerable importance as a wintering area. One nesting site will definitely be affected. There will be increased erosion and resulting siltation caused by disturbance to the landscape. Gases and particulates are potential sources of air pollution. Noise might also be a problem.

764. U.S. Department of the Interior.
1977. Proposed alunite project: final environmental statement. 579 p. U.S. Dep. Interior, Bur. Land Manage., Washington, D.C.

765. U.S. Department of the Interior.
1973. Proposed phosphate leasing on the Osceola National Forest in Florida, E.I.S. 533 p. U.S. Dep. Interior, Bur. Land Manage., Silver Springs, Md. [Available NTIS as EIS-FL-73-1923-D.]

The action under consideration is the issuance of 41 phosphate preference right leases for 52,000 acres on the Osceola National Forest, north central Florida. Issuance of these leases would result in surface mining approximately 30,000 acres of the forest. This mining would result in the permanent removal of 120,000,000 tons of phosphate rock over a period of approximately 30 years. Approximately six endangered species would have their habitat temporarily or permanently removed. Approximately 9,000 acres of the forest would be converted to lakes and ponds.

766. U.S. Department of the Interior.
1971. Proposed oil shale retort research project, Anvil Points, Colorado. U.S. Dep. Interior, Denver, Colo. [Available NTIS as PB-200-436-D.]

767. U.S. Department of the Interior.
1976. Development of phosphate resources in southeastern Idaho: final environmental impact statement. 1253 p. U.S. Dep. Interior, Geol. Surv. (Lead Bur.), Bur. Land Manage., and USDA Forest Service.

768. U.S. Environmental Protection Agency.
1973. Environmental analysis of the uranium fuel cycle. Part I - fuel supply. U.S. Environ. Protec. Agency, Off. Radiation Prog., EPA-520/9-73-003-B, 151 p.

769. U.S. Environmental Protection Agency.
1973. Environmental evaluation of Mines Development, Inc., uranium and vanadium milling operations at Edgemont, South Dakota. U.S. Environ. Protec. Agency, Region VIII, SA/TSB-18, 55 p.

770. U.S. Environmental Protection Agency.
1976. Environmental analysis of the uranium fuel cycle - part IV. U.S. Environ. Protect. Agency, Rep. EPA 520/4-76-017, 16 p. Washington, D.C.

771. Van Tassel, A. J., ed.
1975. The environmental price of energy. 326 p. Lexington Books, D. C. Heath and Company, Lexington, Mass.

772. Walker, E. B.
1971. Energy and environment. In Western Resources Conf. Proc. [Golden, Colo., July 6-8]. p. 87-97. Colo. Sch. Mines, Golden. 275 p.

773. Weaver, G. D.
1973. Environmental hazards of oil-shale development. Ph.D. diss. Johns Hopkins Univ., Baltimore, Md. [Univ. Microfilms, order No. 76-11,235.]

Oil-shale deposits of the Green River formation underlie about 17,000 square miles of land in northwestern Colorado, northeastern Utah, and southwestern Wyoming. A prototype development program for the federally owned lands, which comprise about 72 percent of the total acreage, was announced in June 1971. Commercial development within the near future would necessarily involve mining and surface retorting of the oil-shale rock. A minimum sized plant using underground mining would remove support from beneath 3,000 acres over a 20-year life. The land disturbed by open-pit mining and solid waste disposal could exceed 7,000 acres over a 20-year life. Consumptive water use by industrial processing and related urban needs is expected to range upward to 124,400 acre-feet per year in 1985 and would increase the projected salinity concentration at Hoover Dam by 6 to 10 mg/l. Associated penalty costs to the regional economy, excluding Mexico, would total as much as $800,000 annually. Atmospheric emissions would produce serious air pollution unless the industry exercises careful judgment in the choice of fuels, the removal of stack gases and particulates, and the siting of emission sources. Release from valley sources could produce extraordinarily high ambient concentrations because of the persistent nocturnal inversions that characterize the region.

774. Weir, D. N.
1977. Interaction of placer mining and natural ecosystems in southeast Alaska. In Papers presented at the Second Annual Convention, Alaska Miners Assoc., Anchorage. p. 6-7. Alaska Miners Association, Anchorage.

Plant and animal community studies have been conducted along the Tuluksak River in southwest Alaska since 1962. Placer gold was mined in the area continuously since 1908. The effects of the mining on the natural ecosystem have been studied. The mining disrupts the climax of the forest and allows for secondary succession to commence with the invasion of broad-leafed species such as willows. Bird populations reflect this community diversity. Song birds and predatory birds are diverse with stable numbers.

775. Western Energy and Land Use Team.
1978. Project status reports: a summary. 67 p. U.S. Fish and Wildlife Serv., Biol. Serv. Prog., Fort Collins, Colo.

This report presents updated project summaries of the Western Energy and Land Use Team (WELUT). Projects are organized within four study categories. The categories are: decision processes and information needs; ecological concepts information and rapid assessment techniques; valuation of wildlife; and revegetation, reclamation, restoration, and mitigation.

776. Wildung, R. E., and others.
1977. Terrestrial effects of oil shale development. In Pacific Northwest annual report for 1976 to the ERDA Assistant Administrator for Environment and Safety. p. 2.1-2.8. B. E. Vaughan, ed. Battelle Pacific Northwest Labs, Richland, Wash. 243 p. [Available NTIS as BNWL-2100 (Pt. 2).]

777. Wixson, B. G.
1975. RANN (Research Applied to National Needs) utilization experience. Case study No. 2. Environmental pollution in the New Lead Belt. 25 p. Research Triangle Inst., Research Triangle Park, N.C. [Available NTIS as PB-247 246/2ST.]

The rapid development of the lead mining industry in the "New Lead Belt" of southeastern Missouri caused serious concern as to the effects of lead mining activities on the surrounding virgin forest ecosystem. The objectives of this research are to examine the extent and causes and effects of heavy metal contamination from lead mining and smelting on the surrounding forest, and to develop information for State and Federal agencies so that appropriate corrective action could be taken. This project is a good example of a well-utilized research program having significant value to industry, government, and to the public and regulatory agencies in a cooperative effort to understand and solve a potentially serious problem.

778. Wixson, B. G., E. Bolter, N. L. Gale, and others.
1972. The lead industry as a source of trace metals in the environment. 22 p. Paper presented at the Environmental Resources Conference on Cycling and Control of Metals [Batelle Memorial Institute, Columbus, Ohio, Nov. 1972.]

Mining, milling, transportation,and smelting of lead ore in the Viburnum Trend area of southeastern Missouri are discussed with emphasis placed on pollution introduced into the environment during each of these processes. During the mining and milling processes it is possible for lead and other trace metals to enter the environment from mine water, from dust particles resulting from the grinding process, and from the tailing dams at settling ponds. Lead concentrations exceeded 0.1 ppm 42 times during a year-long survey of stream water. The benthic flora associated with nutrient trapping and recycling were seen as excellent filters for ore particles. Along transportation routes elevated levels of trace elements were found up to 100 ft from the roadway. Open trucks and railroad cars contribute to wind-blown trace metals in the environment. Smelting operations introduce lead, zinc, copper, and cadmium particulate matter into the air. Areas around smelting plants were monitored and fallout decreased with increased distance from the stack.

779. Wixson, B. G., E. Bolter, N. L. Gale, and others.
1977. The Missouri lead study: an interdisciplinary investigation of environmental pollution by lead and other heavy metals from industrial development in the New Lead Belt of southeastern Missouri, vol. I. Research applied to national needs. 566 p. Univ. Missouri, Rolla. [Available NTIS as PB-274 242/7ST.]

An interdisciplinary research team has studied trace contaminants associated with the production of lead for the past 7 years. The study areas are described along with a history of lead mining in Missouri, geology, mine and milling procedures, and lead smelting operations. The "New Lead Belt" is contrasted with century-old mining problems encountered in the "Old Lead Belt" district. Economic benefits are discussed regarding national and international mineral impacts. Research has determined the background values, established natural baselines, and evaluated the lead mining and smelting industry. Sources of trace metals in the environment were found to be associated with the mining-milling operations, transporting ores, and the smelter-refinery process. Information storage and retrieval systems are documented for sample handling. Analytical procedures for studying lead levels in deer bone are presented along with a summary of findings. Volume I focuses on air quality, soils and geochemical studies, water quality studies, and water quality-biological aspects.

780. Wixson, B. G., E. Bolter, N. L. Gale, and others.
1977. The Missouri lead study: an interdisciplinary investigation of environmental pollution by lead and other heavy metals from industrial development in the New Lead Belt of southeastern Missouri, vol. II. Applied science and research applications. 562 p. Univ. Missouri, Rolla. [Available NTIS as PB-281 859/9ST.]

An interdisciplinary research team has studied trace contaminants associated with the production of lead for the past 7 years. The study areas described along with a history of lead mining in Missouri, geology, mine and milling procedures, and lead smelting operations. The "New Lead Belt" is contrasted with century-old mining problems encountered in the "Old Lead Belt" district. Economic benefits are discussed regarding national and international mineral impacts. Research has determined the background values, established natural baselines, and evaluated the lead mining and smelting industry. Sources of trace metals in the environment were found to be associated with the mining-milling operations, transporting ores, and the smelter-refinery process. Information storage and retrieval systems are documented for sample handling. Analytical procedures for studying lead levels in deer bone are presented along with a summary of findings. Other advanced analytical studies are described for thallium and the use of *Drosphila* (fruit flies) as an environmental monitor. Volume II focuses on accumulation of toxic heavy metals by vegetation and remote sensing data analysis and computer aided sampling.

N. Miscellaneous Citations

Section N contains a variety of citations, some from popular journals and some written for the nonscientific community.

781. Bishop, J., Jr.
1974. Oil shale: bonanza or bust for the Rockies? Natl. Wildl. 12(3):11.

782. Business Week.
1971. Cutting Florida's strip mining ills. Business Week 2157:43.

783. Business Week.
1973. An open-pit dilemma for Butte, Montana. Business Week 2308:92,94.

784. Caudill, H. M.
1973. Protecting our environment: farming versus strip mining. Current (156): 37-45.

785. Chaney, E.
1977. Phosphate fate will determine Idaho high country's fate. Audubon 79(2): 123-126.

786. Engineering and Mining Journal.
1973. Cominco collects 1970's dividend from 1920's pollution control effort. Eng. and Mine J. 174(9):121-124.

787. Evans, K. A., E. W. Uhleman, and P. A. Eky.
1978. Atlas of western surface-mined lands: coal, uranium, and phosphate. 394 p. Western Energy and Land Use Team, Off. Biol. Serv., U.S. Fish and Wildlife Serv., Fort Collins, Colo.

788. Goldstein, J.
1975. "New" fertilizers vs. strip mining. Organic Garden. and Farm. 22(6):98-99.

789. Johnson, C., and J. Gropper.
1976. Sand and gravel operations: conflicts and choices. Utah Sci. 37(1):14-19.

790. Li, T. M.
1975. Environmental compliance assures future production at Jaquays asbestos operation. Mining Eng. 27(3):40-45.

791. Line, L., ed.
1973. What we save now: an Audubon primer of defense. 438 p. Natl. Audubon Soc.

792. Loucks, R. A.
1977. Occidental vertical modified in situ process for the recovery of oil from oil shale: phase I. Occidental Oil Shale, Inc., Grand Junction, Colo.

Since early 1973, Occidental Oil Shale, Inc. (OXY) has processed three small-scale modified in situ retorts (retorts 1E, 2E, and 3E) in its research mine, and is currently processing the second large-sized retort (retort 5) in its development mine; both mines are located on OXY's D.A. shale property northeast of De Beque, Colo. Progress of the project since November 1, 1976, is summarized starting with the preblast activities and the startup for retort 5, through the mining progress in the formation of retort 6. The environmental aspects including the required permits are discussed along with the geology and hydrology data from the C-B tract. Results of various studies on potential markets for shale oil are presented and the schedules presented in OXY's proposal to ERDA are compared with the schedules achieved through October 1977. A section is included on future plans.

793. Mamen, C.
1973. Island copper: ecology wise. Can. Mining J. 94(7):31-33.

794. Soucie, G.
1973. Oil shale: details of Interior's prototype program emerge from 3,200-page report. Audubon 75(6):125-127.

795. Soucie, G.
1973. Oil shale: Pandora's new box. In What we save now: an Audubon primer of defense. p. 319-328. L. Line, ed. Natl. Audubon Soc. 438 p.

796. Sumner, D., and C. Johnson.
1974. The great shale robbery. Sierra Club Bull. 59(3):11-14,16.

797. World Mining.
1970. Miners and conservationists discuss ecology in the arid environment. World Mining 6(6):28-29.

APPENDIX I

CROSS-REFERENCE INDEX OF ENVIRONMENTAL EFFECTS

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
AIR RELATED EFFECTS				
Mass emissions	273,274	259		
Fine particles	267,532			
General air quality	262,263,270	254,260,264		Monitoring
Specific:				
Asbestos	252,266,269	256	255	
Sulfur dioxide	275			
Silver	258			
Uranium	243			
Barium	245			
Boron	246			
Copper	247			
Cadmium	250			
Iron mine	272	272		
Lead	244			
Nickel	251,271			
Manganese	268			
Molybdenum	257			
Selenium	248			
Vanadium	253			
Zinc	249			
Respirable dust		261,265		
FAUNA RELATED EFFECTS				
Arthropod	517			
Fish	515		505,506,507,513	
Wildlife, general	112,113,498,512		505,506,507,513	
Wildlife habitat	515	499,502,503,510	509,510,513	
Small mammals	511		101	
Grazing (domestic)	500,501			
Endangered species			509	
Birds	103,108,144			
FLORA RELATED EFFECTS				
Accumulation of heavy metals	482,485,486,488 489,490,491,493 495,496,601		487	
Negative responses to pollution	140,254,260,264 483,496,641,650		61	Lichen
Ecology:				
Population dynamics			484	
Reproductive biology			5,120,121,131 492,508,570	

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
Ecology: (con.)				
Plant succession			110,111,566,584	
Species adaptability and usefulness in revegetation		671	126,127,171,568 571,577,581,604 613,615,618,619 620,266,650	
Mycorrhiza		143,157		
GENERAL ENVIRONMENTAL IMPACT				
Bentonite	723			
Clay	698			
Coal			62,86	
Copper	704,746	215,227		
Energy/fuels	675,676,681,690 691,696,771,772 735		744	
Lead	777,778,779,780			
Lignite	706,707			
Metals	726			
Minerals	697,712,722,725 755		745	
Molybdenum	679			
Ocean mining (manganese)	298,709,713,740 741,742		32	
Oil shale	221,682,683,684 685,687,689,705 707,717,736,750 757-759,766,773 776	200,219,680	36,711,747,750	
Phosphate	716,717,749,763 765,767	217		
Sand and gravel	688,222,734	199,204,210,213 220,224,225,185		
Strip mining	686,692,760			
Tar sands	695			
Uranium	145,674,693,708 714,724,728,729 730,731,738,739 753,761		678,71,59	

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
GENERAL ENVIRONMENTAL IMPACT (con.)				
Zinc	677			
HEALTH				
General			31	
Uranium	519,522,525,527 528,530	520	59	
Radioactivity, radon gas, etc.	521,522,523,524	524		
Metal miners	115			
MISCELLANEOUS				
Data bases			1-94,699-702 710,720,747 748,775	
Environmental measurement			105	
Archaeology	535			
Noise	537			
Trace minerals	532			
Recreation		220,225,232		
REVEGETATION AND RECLAMATION				
Acidic sites	588	123,576		
Aluminum		610		
Arid-West	636	560,636	11,12,15,18,27 35,52,53,55,75 85,93	
Bentonite	154	99,100,104,157 158,191	566	Research
Barrow pits		544		
Coal	632	123,644	6,17,56,92	
Copper	564	126,127,183,562 563,565,602,603 604,629,639,649 659		

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
REVEGETATION AND RECLAMATION (con.)				
Coastal estuaries, marsh		600,626	12	
Drastically disturbed areas		190	16,40,41,48,65,76 91,540	
Dolomite, limestone		181		
Fluorspar		585,586,587		
Gold		591		
Iron		611,648,649		
Kaolin clay		606,607,608		
Lead-zinc		599,637,638,667		
Manganese		573		
Molybdenum		546		
Mill tailings		117,118,567	235,239,240	
Mine water impoundment		543		
Oil shale	160	98,128,555,558 579,655,664		
Phosphate		123,173,572,574 582,623,640,666		
Surface mines		96,153,180,562 635	1,4,9,11,25,26,43 45,47,63,77,78,79 80,81	
Sand and gravel	650	589,624,627	653	
Tar sands		654		
Tundra	159,588,593,614	109,159,305,546 547,548,549,550 551,552,553,554 557,616,617,618 672	13,72	
Uranium	161,596	592,609,625,643	660	
Revegetation potential		561,598,628	597	
Reclamation planning			30,46,51,630	
Economic aspects			10,236,237,242	

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
REVEGETATION AND RECLAMATION (con.)				
Machinery for reclamation			119,163,545	
Techniques for reclamation			172,542,582,593 605,612,628,634 646,656,659,671	
Guidelines, guide books, reference books			216,223,597,642 645,656,657,662 663	
Erosion control			2	
SOLID WASTE				
Management/disposal	398,443,465,476	398,410,437,440	409,470,475	Research needs
Use of	401	396,406,407,433,451	14,408	
SPOILS AND TAILINGS				
Tailings, general	186,402	480	57	Weathering
Tailings, dams and ponds	479	431,479	474	
Tailings, stability	442	137,415	33	
Tailings, specific:				
Aluminum		610		
Asbestos		621		
Bauxite muds	460	460		
Bentonite	106	99,100,104,157 158,191		
Copper	139,448,466,564	126,127,183,461 562,563,565,602 603	604,639,649,659	
Fluorspar		585,586,587		
Gold		591		
Iron ore		611,648,649		
Kaolin clay	453	606,608,609		
Lead	441	637,638,667		
Limestone		435		
Manganese		573		
Oil shale	462,472	98,128,437,558,579 655,664		
Phosphate slimes and tailings	405,442,444,446 473	122,395,403,454 471,574,582,640 666		
Tar sands	444	453	654	

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
Tailings specific: (con.)				
Uranium	129,135,140,196 412,414,417-428	129,397,400,439 592,609,625,643 660		
Zinc		416		
Soil chemistry, general	170,402,448,453			
Saline and sodic		164	89	
Heavy metals	399			
Treatments, general		457,458		
Amendments		146,151,165,177		
Mulch		167,169,176		
Microorganisms	139,182	184,394,467 560		
WATER RELATED EFFECTS				
General water quality	107,287,312,330 386,694	276	88	Navigable waters
Geochemical	281,293,294,343			
Specific water quality:				
Asbestos	309			
Bentonite	376			
Copper	295,371,380			
Gold	296	296		
Heavy metals	142,278,280,320 391		66	Mobilization
Hazardous	130,288,306,316 326			
Limestone		317		
Lead-zinc	295,280,304,333 370,371	374,328,375,392		
Mercury	296	296		
Molybdenum	296	296		
Phosphate	277,306,311,313 316,326,387,388	277		
Placer mine	192,285	291		
Oil shale	283,334,336,338 339			
Silver	296	296		
Tar sands	384			
Thallium	310,393			
Tungsten	296	296		

Subject	Citations describing problems	Citations describing solutions	Other citations	Remarks
Specific water quality: (con.)				
Uranium	130,288,307,308 314,315,321,322 323,324,325,327 332,342,377	708		
Effluent	290,312	279	289,303	Guidelines on limitations
Acid mine drainage	124,352,358,364	178,347-369 (except 352,358 364)	4,10,49,60	
Hydrology	311,335,338	305	534	
Erosion	179	2		
Stream channel	344	136		
Ground water	155,189,308,313 318,325,338	148,300		
Water requirement (consumptive use)	301,319,331,334 345	148,300	7	Management
Water resources	297		8	
Abandoned mine effluent	331,333,336,455	178,331		

APPENDIX II

NATIONAL TRENDS
MATRIX SUMMARY INDEX

Impacts	COMMODITIES	COASTAL PLAINS -eastern phosphates	-gypsum	CLAYS & BAUXITE -clays	-bauxite	OPEN PIT (DRY) -copper	-molybdenum	-western phosphate	OPEN PIT (WET) -iron	-other	-copper/nickel	-placer mining	OIL SHALE/TAR SAND -oil shale
I. AIR POLLUTION									272	268	271		
A. Fugitive dust						261 265	261 265		261 265 266	261 265 639			
B. Toxic emissions (asbestos, radon)							257		252 262		251 256		
II. SURFACE WATER POLLUTION						*295	* 296					285	179 189
A. Chemical													
1) sedimentation												291	
2) radio-activity		316 326						316 326					
3) process effluent		277							290 303		303		
4) heavy metals						142 C21			C21		C21		
5) salinity-buildup and asbestos													283
6) acid mine drainage	- - - - - - See section IIIF, citations 347-369, and 4,10,49,60 - - - - - -				*	*					*		
B. Physical													
1) Stream channel quarry ponds												H5	
2) consumptive use		300											7
3) water management		346 300 138 302											301 334 336 319

Commodities												
-tar sands	SAND & GRAVEL -sand & gravel	-crushed stone	-limestone	UNDERGROUND -sulfides	-solution mining	-exploration	NATURAL BUILDING STONE	DISCONTINUOUS ORE BODIES -vanadium	-uranium	-bentonite	GENERAL CITATIONS	REMARKS
270 275											273,G1,G3[1]	
	261 265	261 265		261 265			261 265				261,265,267 *415,G2,G4 G6	*Dust abatement
				244 250				253	*243		274	*See "Human Health," p. 132
386			*317	*295 *297 *328 333					*327	107 134	*331,333 336,F19	*Water pollution control methods
									C7		2,C2,C3,C11 C22	
									287,288 324,332 315,321 322,323 F12,F22			
				303 312,343 344				303	303 342			
				278 280,281, 320							66,310 F11,F20	
385											309	
- - -	- - -	- - -	- - -	*178	- - -	- - -	- - -	- - -	- - -	- - -	124,125,8A	*Commodities with acid drainage problems
	F9,F10 F13,H8											
											F15,F16,F17	

[1] Citations with a letter preceding the numeral refer to comments in Section I.

Impacts	COMMODITIES	COASTAL PLAINS -eastern phosphates	-gypsum	CLAYS & BAUXITE -clays	-bauxite	OPEN PIT (DRY) -copper	-molybdenum	-western phosphate	OPEN PIT (WET) -iron	-other	-copper/nickel	-placer mining	OIL SHALE/TAR SAND -oil shale
	Commodities												
C. Biological 1) effects on organisms		388 505 506 507			380	381 383		387	393	371 372		192	175 187 188
2) effects on aquatic habitat					380	382 383							
III. GROUND WATER POLLUTION								313					148 338
A. Toxic contaminates		306				294 F4					F4		
B. Hydraulic impacts		311				155							335 339
IV. RADIOACTIVITY													
V. RECLAMATION		74,84 574 582 630 666		607 608 C17		165 183 562 563 603 E12	672	173 574 582 C9	648 649 E11 E21	573 621 E11	562 563 629 635 649		36,64 97,98 128,147 555,647 655
A. Species for revegetation				641		127 581 604	584	123					664
B. Soils and spoils problems		122 405 444 446		453		448 467 564 D6		170 394	611	D6	D6 E19	564	402 462 472 D4
C. Climatic factors and stubborn conditions		473		606	610	565 576 602 B10	546- 554 588 B12						160 558 579

Commodities												
-tar sands	SAND & GRAVEL -sand & gravel	-crushed stone	-limestone	UNDERGROUND -sulfides	-solution mining	-exploration	NATURAL BUILDING STONE	DISCONTINUOUS ORE BODIES -vanadium	-uranium	-bentonite	GENERAL CITATIONS	REMARKS
385 386				370 374,375 378,391					377	376	102,373,379 391,392,393 F21,H3,H5	
	H6 H7 H8									132 133 376	384 C3	See WILDLIFE, "fisheries," next page.
				318							6,F14	
									286,287 307,308 315,F4		309,F18,K13	
									325		F1,F2,F3	
									412 414,418 428,K4 K6,K12		129,145,194 196,K11	See SURFACE WATER POLLUTION, p. 135, and HEALTH, p. 132
561 598 654	589 590 624 627 653	155	180 181	585 586 591 599 637 638	44		C1 C4 C16	161	194 196 592 609 643 E4	146 154 157 176 E4 E20	1-94,96,101 116,117,143 151,153,159 163,167,177 540,543,545 597,601,605 612,633,636 639,640,644 645,650,661 662,663,671	
									625	99 E3 E7	120,121,123 131,171,563 568,570,571 614,615-618 620,622	
444 E13 E14	646 650			399 467 D7					34,35, D11 D14	106 D1 E16	61,89,169 560,650,D2 D3,D5,D8,D9 D10,D12,D13	
	600			587				596	596 B5 B6 B11 B12	B5 B6 B11	13,14,27,72 109,110,111 542,551,552 557,578,593 614,B1,B2,B3 B4,B7,B8,B9 B13,B14	

		Commodities											
Impacts	COMMODITIES	COASTAL PLAINS -eastern phosphates	-gypsum	CLAYS & BAUXITE -clays	-bauxite	OPEN PIT (DRY) -copper	-molybdenum	-western phosphate	OPEN PIT (WET) -iron	-other	-copper/nickel	-placer mining	OIL SHALE/TAR SAND -oil shale
D. Tailings, slimes and waste(management and disposal)		122 395 403 454 471 572 623 F7	474		460	461		442	451 477 478 481		466 639 659		410 437
E. Effects on plants						126 483			488 496	485	483 488		
VI. WILDLIFE		505 509									635		498 512
A. Effects on organisms		506 507											
B. Alteration of habitat		509											H14
1) fisheries						381 382 393		387				192 H5	
2) wet lands		388										H5	
3) terrestrial													
4) mitigation of negative effects													
C. Threatened or endangered species		509											
VII. CULTURAL IMPACTS													535
VIII. LAND USE (planning and policy)		212 217		208		215 227							200 204 206 207 221

Commodities												
-tar sands	SAND & GRAVEL -sand & gravel	-crushed stone	-limestone	UNDERGROUND -sulfides	-solution mining	-exploration	NATURAL BUILDING STONE	DISCONTINUOUS ORE BODIES -vanadium	-uranium	-bentonite	GENERAL CITATIONS	REMARKS
457		435		416 441 476			435	33	34,35 395 400 429 430 439 660 C18	631	118,396,398 401,406,407 408,409,433 440,443,465 628,C5,C8,C13 C19	
				482 484,486 487,489 495				K12		104 158 191 198 198	658,K10	
				511							475,513,517 595,637,652 H4	
	499 626			392 393						112 113 144	513,H2,H11 H12,*H10	*Migration block
	H6 H7			391				377			390,H3,H5	
	H7 H8									108 132 133 376	66,H4	
										103 144 514	502	
	499										502,503,510 513,H13	
											H9	
											K7	
185 199,201 203,210 213,214 220,222 224,229 233											19,44,51,205 211,212,216 218,223,226 228,231,232	

Impacts	COMMODITIES	COASTAL PLAINS -eastern phosphates	-gypsum	CLAYS & BAUXITE -clays	-bauxite	OPEN PIT (DRY) -copper	-molybdenum	-western phosphate	OPEN PIT (WET) -iron	-other	-copper/nickel	-placer mining	OIL SHALE/TAR SAND -oil shale
	Commodities												
IX. HUMAN HEALTH		521											
X. GENERAL IMPACTS		716 749 765		698		746	679	716 717 763 767					704
XI. OTHER IMPACTS (noise, roads)													
XII. ECONOMIC						236							236 242
XIII. LEGAL		235											

Commodities												
-tar sands	SAND & GRAVEL -sand & gravel	-crushed stone	-limestone	UNDERGROUND -sulfides	-solution mining	-exploration	NATURAL BUILDING STONE	DISCONTINUOUS ORE BODIES -vanadium	-uranium	-bentonite	GENERAL CITATIONS	REMARKS
										35,59 519 520 522 530 K14	31,115	
	*185 *199 *204 *210 *213 *220 222 *224 *225 688 734	222 688 734		677 776- 780					71 145 674 678 693 712 714 724 728- 731 738 739 753 761		536	*Mitigation
	536 537 K3	536					K2 K5					K1,K5
237											9,K8 239,240	

Richardson, Bland Z., and Marilyn Marshall Pratt, compilers. 1980. Environmental effects of surface mining of minerals other than coal: annotated bibliography and summary report. USDA For. Serv. Gen. Tech. Rep. INT-95, 145 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

This bibliography contains annotated references to literature about the environmental effects of surface mining for minerals other than coal. Each reference is indexed by commodity, general subject, and environmental problem. The publication includes a section of references to unpublished, "soft" literature and a summary of professional concerns about mining impacts throughout the United States.

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The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

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